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Cold Weather Decontamination Study - McCoy I

by

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U. S. ARMY CHEMICAL CORPS

NUCLEAR DEFENSE LABORATORY

ARMY CHEMICAL CENTER • MARYLAND

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FOREWORD

This is an interim report that shows progress through FY-61. Conclusions and application of data must be viewed with caution because they are susceptible to change as further work develops.

The work was authorized under DASA Project A-8 10.06, Cold Weather Decontamination, Project 4X12-01-001-02, Decontamination (U), with supplemental funding from the U. S. Navy Bureau of Yards and Docks. The work was started in February 1960 and is being continued. Completion is expected in June 1962.

Acknowledgments

The authors wish to acknowledge the assistance of the personnel of the U. S. Naval Radiological Defense Laboratory, who designed and procured the fallout simulant production apparatus, and of the Cook Electric Company, who conducted the field phase of the operation.

Notice

Disposition

When this document has served its purpose, DESTROY it. DO NOT return the document to the U. S. Army Nuclear Defense Laboratory.

DIGEST

The objective of this work, as reported herein, is to obtain necessary data for preparation of a cold-weather supplement to technical manual, TM 3-225, Radiological Recovery of Fixed Military Installations. This report covers progress during FY-61.

A facility capable of producing 500-lb batches of fallout simulant, tagged with 5 curies of lanthanum-140, was designed, installed, and operated at Camp McCoy, Wisconsin. A series of decontamination tests, limited by improper weather conditions, was conducted using techniques of snow plowing, power sweeping, and fire hosing.

The following evidence, based on the fragmentary information obtained during this test series, should be considered tentative and subject to change.

1. The decontamination techniques of grading, sweeping, and hosing on applicable coldweather surfaces are less effective than the same techniques on corresponding temperate-weather surfaces.

2. Mechanized sweeping and vacuum sweeping of packed snow and frozen soil are effective decontamination techniques.

3. The possibly unique decontamination technique of water hosing packed snow and frozen soil is apparently without merit.

Radiation dosage was kept to a minimum by the experimenters and no residual dosage problems were encountered. Normal camp activities were resumed 30 days after the conclusion of the testing period.

MILITARY APPLICATION

The available decontamination technical manuals, TM 3-220* and TM 3-225**, are inadequate for planning radiological countermeasures under cold-weather conditions. This report covers the progress of the FY-61 effort to obtain information to correct this deficiency.

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* Decontamination. TM 3-220. October 1953

** Radiological Recovery of Fixed Military Installations. TM 3-225. (NAVDOCKS TP-PL-13). Int. rev. April 1958.

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COLD WEATHER DECONTAMINATION STUDY - McCOY I

1. INTRODUCTION.

A. Objective.

The objective of this study is to conduct experiments and collate data pertinent to radiological decontamination under cold-weather conditions, so that the necessary data is available for publications of a cold-weather addendum to technical manual TM 3-225 (NAVDOCKS TP-PL-13), Radiological Recovery of Fixed Military Installations.

B. Justification and Requirements.

TM-3-225 presents methods and data necessary to perform decontamination operations on fixed military installations under temperate-weather conditions. The application of basic recovery criteria contained in this manual will have to be modified, or alternate methods employed, for decontamination operations under cold-weather conditions. Large portions of the United States could be affected for an extended period of time by cold weather (-10° to +32°F), thus affecting any contemplated decontamination operation.

This project is part of the FY-61 Defense Atomic Support Agency (DASA) coordinated program, Nuclear Weapons Effects - Fallout, with additional support from the U. S. Navy Bureau of Yards and Docks.

C. Historical Background.

Radiological decontamination has been intensively investigated during the past decade by a number of different agencies. The experimental effort has ranged from laboratory studies, through nuclear weapons test operations, to comprehensive studies involving areas up to 5 acres. Practically all of this work has been accomplished under temperate-environmental conditions and has been previously reported.[1-23] The manual, TM 3-225, Radiological Recovery of Fixed Military Installations,[24] was based on the results of these investigations.

In 1958, the U. S. Naval Radiological Defense Laboratory (USNRDL) prepared a study of the potential delay in radiological recovery due to cold weather encountered in the United States.[25] In this study, the concept of a hosing cutoff temperature was introduced. Operations involving water would not be considered feasible below this conceived value. Since there were no data upon which to estimate the water hosing cutoff temperature, the analysis of data presented the potential delay for a series of possible cutoff temperatures down to 0°F. For a hypothethical cutoff temperature of 0°F, negligible delay would result for normal winter temperatures based

on climatological studies of the United States; however, delays would increase if the cutoff temperature were higher. At a cutoff temperature of 30°F, the mission recovery time would be delayed for more than a month.

Early in 1960, the Naval Civil Engineering Laboratory (NCEL), with the assistance of the U. S. Army Chemical Corps, conducted a series of tests at Fort Greely and Point Barrow, Alaska, to determine (1) the cutoff temperature of water for hosing and building washdown, (2) the effectiveness of power sweepers on packed snow, and (3) the surface softening of frozen ground by freezing point depressants. Local sand (nonradioactive) was used as the fallout simulant in these tests, thus yielding only qualitative results. From these tests, the following information was obtained: (1) water spray from fire hoses and building washdown nozzles did not freeze at windchill values to 1450 at 9°F (see Windchill Index, figure A-2, appendix A) where windchill is defined as the combined effect of wind and air temperature on heated bodies, and is expressed in kilocalories per square meter per hour; (2) slow leaks and windborne mist did freeze; (3) the water runoff did not immediately freeze, and still runoff water took 15 min to crust when in contact with ocean ice at 7°F and at a windchill index of 1200; (4) power sweepers were effective on packed snow except at temperatures near freezing; (5) at these near-freezing temperatures, surface softening caused by the onset of thawing apparently trapped the contaminant, preventing the sweeper from effectively picking it up. The use of salt depressants to soften ground surface did not appear to be effective.

A report of known cold-weather decontamination information[26] has been prepared by NCEL, largely based on the foregoing tests, to form the basis of an interim cold-weather supplement to TM 3-225.

The findings of a background literature search by this Laboratory on cogent coldwweather factors are summarized in appendix A.

II. EXPERIMENTAL PROCEDURES AND FACILITIES.

A. Operational Plans.

A series of decontamination trials (table 1) was planned to be conducted in the field at temperatures between -10° and +32°F. The operational test site chosen was Camp McCoy, Wisconsin, where the proper environmental weather conditions would be expected and where adequate logistic support and test areas were available. A discussion of test-site requirements and a description of the Camp McCoy site are presented in detail in appendix B. Each decontamination trial was planned to be conducted on a 20- by 100-ft surface area. This size area is large enough for mechanical equipment to operate efficiently, and for an adequate number of radiation measurements to be taken.

TABLE 1

DECONTAMINATION TRIALS PLANNED

Type of surface contaminated	Method of decontamination	Temperature range of test: From -10° to 5°F	From 5° to 20°F	From 20° to 32°F
Bare frozen ground	Fire hosing	X	X	X
	Mechanized sweeping	X	X	X
	Mechanized blade scraping	X		
	Vacuum sweeping	X	X	X
Bare asphalt pavement	Fire hosing	X		
	Mechanized sweeping	X		
Bare concrete pavement	Fire hosing	X		
	Mechanized sweeping	X		
Packed snow	Fire hosing	X	X	X
	Vacuum sweeping	X	X	X
	Mechanized sweeping	X	X	X
	Mechanized blade scraping	X	X	X
Packed snow, covered by loose snow	Mechanized scraping and/or mechanized sweeping	X	X	X
Loose snow	Mechanized blade scraping	X		
	Mechanized rotary scraping	X		
Roofs (bare)	Fire hosing	X	X	X

The only deviation in test-area size was the use of a 20- by 60-ft building roof.

Operations involved preparing a radiation fallout simulant, spreading the simulant on test areas, performing decontamination trials, and finally, disposing of the radioactive waste.

B. Fallout Simulant.

The USNRDL has developed a fallout simulant consisting of lanthanum-140 (La^{140}) tagged smooth sand. Much of the recent experimentation at Camp Parks has been conducted with a 150μ to 300μ simulant deposited at a mass level of 50 gm/sq ft. These physical characteristics of fallout correspond to their model downwind-fallout deposit from a land-surface fission detonation of 1-Mt yield at the H+1 hr intensity of 2,000 r/hr. For convenience in comparison of results, these fallout parameters were also used by this project.

The sand was coated with La^{140} as a radioactive tracer, at a specific activity of 10 μC/gm. This isotope has several gamma-ray energies in the range of 0.33 to 3 Mev, with principal peaks at 0.33, 0.49, 0.815, and 1.6 Mev. Its half life of 40.2 hr makes it a convenient tracer, in that rapid radioactive decay would eventually eliminate any residual activity. The tagged sand was further treated by coating with sodium silicate solution and then by baking for 1 hr at 1000°C. This treatment was necessary to firmly bond the isotope to the sand, in order to prevent any leaching of activity to the environment.

The fallout simulant was loaded into a dump truck equipped with a Burch Hydron spreader. This device is a dump-truck accessory designed to uniformly spread granular material onto road surfaces. In operation, a path approximately 7 ft wide could be spread on pavement, soil, and packed snow; thus, three adjacent passes were necessary to contaminate the 20-ft wide test areas. For the roof test, a 2-ft wide Scott lawn spreader, equipped with extension handle and tachometer, was used for contamination operations. Radiation fields of 30 mr/hr intensity levels were produced.

A detailed description of the fallout-simulant preparation, handling, and spreading is presented in appendix C.

C. Mechanized Equipment Operation.

The following mechanized equipment was used in the preparation of test areas and in the various decontamination tests:

Front-End Loader, Crawler, D-4 Tractor
Dump Truck, 2½ Ton, 6 x 6
Bulldozer, D-8

Motor Grader, Caterpillar, Model 12
Pneumatic Roller, Towed
Sweeper, Vacuum, Tennant, Model 100
Sweeper, Mechanized, Conveyor, Model 1000-4
Fire Engine, Pumper

The front-end loader and dump truck were used for general utility work, such as removal of windrows of snow from blade-plowing (scraping) operations and removal of radioactive waste resulting from sweeping operations. Because it was necessary to remove the snow cover, the bulldozer was used to prepare the bare, frozen soil test areas. The Model 12 Caterpillar was used as a mechanized grader to finish-grade the areas scraped by the bulldozer. It was also used as a blade-type snow plow for decontamination operations. The pneumatic roller was used to prepare packed-snow surfaces in the test area. It was pulled by either the front-end loader or bulldozer. The two sweepers and fire engine were used as decontamination apparatus. Both sweepers incorporated horizontal road brooms that swept material into a bin. The Tennant machine also incorporated a vacuum pickup and cloth filters to retain the dust generated by the road broom. The fire engine was used to boost hydrant pressures to supply two 1½-in. hose streams at 40-psi nozzle pressure.

The decontamination operations were conducted in the following manner:

1. <u>Motor Grading</u>.

Packed snow was decontaminated by scraping approximately 2 in. of snow from the surface. All scraping passes were made with the grader moving in the same direction, and windrows formed were subsequently pushed aside by the following overlapping pass. The final windrows were left about 10 ft to the side of the test area. The operation was then repeated to remove another 2-in. layer from the surface of the test area.

Snow windrows were removed from the vicinity of the test areas by loading the snow into a dump truck with the front-end loader. The contaminated snow was transported to the dump area.

2. <u>Mechanized Sweeping</u>.

The test areas were decontaminated with the mechanized sweeper by making several slightly overlapping lengthwise passes over the area, all in the same direction. The sweeper-collection bin was emptied in the dump area.

3. Vacuum Sweeping.

The test areas were decontaminated with the vacuum sweeper by making lengthwise passes over the area in both directions. The sweeper-collection bin was emptied in the dump area.

4. Fire Hosing.

The land areas were firehosed by two men, each with a 1½-in. hose. The hosing started at one end of the area and worked to the other end. The roofs were washed by lobbing the water onto them from ground positions. All hosing operations were conducted by personnel of the Post fire department.

D. Radiological Instruments and Survey Procedures.

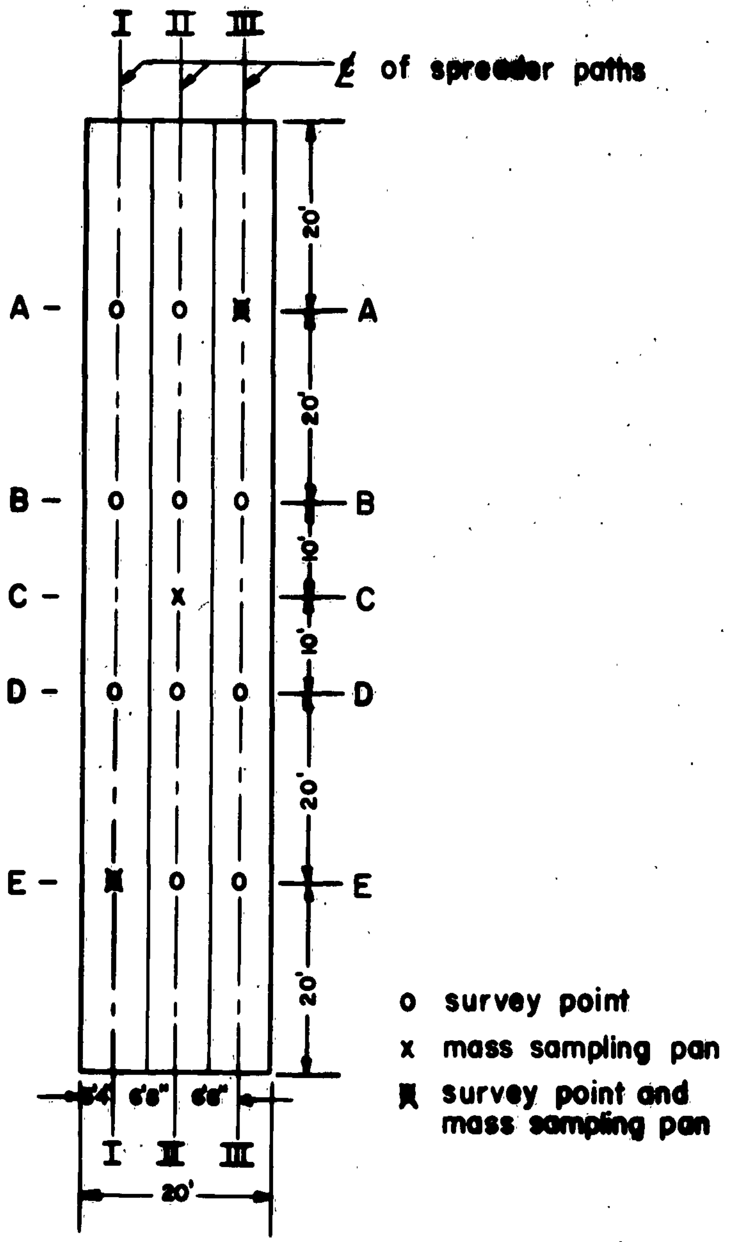
The AN-PDR/27c Radiac was employed for all radiological measurements. A portable 3-ft-high wooden stand was used in conjunction with the Radiac to support the instrument at a constant height, and to reduce the difficulties associated with handling small instruments with heavily gloved hands. On the 20- by 100-ft areas, measurements were made at 20-ft intervals along the centerline of each of the three adjacent spreads of simulant, as shown in figure 1. The same grid intersection points were used for measurements on the shorter 20- by 60-ft roof.

Measurements were taken before and after decontamination. The natural background was insignificant as compared to all actual radiation levels and could be ignored.

E. Narrative Outline of Operation Schedule.

During the period from July to November 1960, the simulant production apparatus was designed, components purchased, and necessary shop work performed at the USNRDL facilities at San Francisco and Camp Parks, California. Also, during this period, the test sites under consideration were inspected, selection was made, and plans formulated for the conduct of tests. Official permission was obtained from Headquarters, Fifth U. S. Army, for the use of Camp McCoy and the available logistics supplies there. In order to insure that the restrictive set-up and testing-period time limitations could be met and that ample technical manpower would be available, it was decided to negotiate a contract with a research and development concern. Such a contract was negotiated and let to the Cook Research Laboratories of Morton Grove, Illinois, a division of Cook Electric Company.

The simulant-production apparatus and other test gear were shipped to Camp McCoy in December 1960. The contract was effective 3 January 1961 and the field-effort phase was begun immediately.



FIGURE

SURVEY GRID FOR THREE SPREADS OF SIMULANT

January and February 1961 were spent setting up the hot cell and production apparatus, installing sand-bag shielding around expected high-dosage sources and occupied operator positions, training personnel, and conducting dry runs.

By 1 March 1961 the project was in a ready state for testing; however, temperatures were unseasonably warm, and there was a lack of snow until the week of 5 March 1961. This snow lasted only long enough for a tracer-level hot run. Difficulties in hot plant operation and field procedures were ironed out, however, and upon the arrival of a significant snowfall during the following week it was possible to conduct nine of the desired tests. In this period, the daytime temperatures rose above the freezing mark, while the night-time temperatures fell within the range of 10° and 25°F. It was necessary to run the tests during the predawn to 0900 hr period to experience suitable environmental conditions. By the end of the week a thaw set in, effectively halting any further testing for that season.

III. EXPERIMENTAL RESULTS AND DISCUSSION.

A. Results.

The data collected from the field tests consist of (1) radiation measurements over the test area before and after decontamination, (2) mass level and specific activity of the simulant, (3) decontamination time and operator dose rate, and (4) air temperature. The detailed data, as summarized in table 2 of the text, are given in appendix D.

The results from the analysis of data are given in table 3. Two values for per cent decontamination are given for each test. These values were derived by considering a test area's mean radiation measurements for the total area per cent decontamination, and by using each measurement position per cent decontamination to obtain an average value for the test.

Based only on the radiation measurement data, comparisons of the various test results were made by statistical analysis using an 80% confidence level. The results of these comparisons are as follows:

1. There is no significant decontamination of packed snow or bare frozen ground by firehosing.

2. There is no significant difference in the decontamination of bare frozen ground by vacuum sweeping or mechanized sweeping techniques.

3. There is a significant difference between the first and second decontamination passes of the mechanized sweeper on bare frozen ground.

TABLE 2

SUMMARY OF RADIATION MEASUREMENT DATA

Test number	Surface type a/	Size of area	Method of decontamination	Atmospheric Temperature	Contaminated area			Decontaminated area (one pass)		Decontaminated area (two passes)	
					Mass mean level	Specific activity	Mean radiation level b/	Decontamination time	Mean radiation level b/	Decontamination time	Mean radiation level b/
		ft		°F	g/ft²	μc/g	mr/hr	min	mr/hr	min	mr/hr
I	BFG	100 x 20	VS	31	42.4	4.0	23.6	3	1.9	---	---
II	BFG	100 x 20	MS	31	44.0	3.8	22.1	6	6.6	15	2.8
III	BFG	100 x 20	FH	8	32.3	9.0	28.3	10	26.3	---	---
IV	PS	100 x 20	FH	13	47.0	8.7	30.1	20	27.5	---	---
V	BR	60 x 20	FH	21	--- d/	8.8	18.5	15	3.1	---	---
VI	PS	100 x 20	MG	24	47.8	9.3	26.1	15	7.1	60 c/	7.1 c/
VII	PS	100 x 20	VS	25	26.7	8.5	25.3	20	8.3	---	---
VIII	PS	100 x 20	MS	26	33.7	8.9	31.0	-- d/	-- d/	20	8.0
IX	LS on PS	100 x 20	MG	24	31.9	5.4	21.5	10	8.0	---	---

a/ BFG Bare frozen ground; PS Packed snow; LS Loose snow; BR Bare roof; VS Vacuum sweeping; MS Mechanized sweeping; MG Mechanized grading (blade scraping or "snow plow"); FH Fire hosing
b/ Radiation level readings corrected for position over area, instrument calibration, and decay
c/ Data for after windrow removal
d/ No data

TABLE 3

DECONTAMINATION PERCENTAGES IN FIELD TESTS

Test number	Surface type *	Method of decontamination **	Area of decontamination		Measurement point of decontamination	
			Range for total area	Average for total area	Range for total area	Average for total area
			%		%	
I	BFG	VS	89.0-94.9	91.9	88.9-94.9	91.9
II	BFG	MS	83.3-91.4	87.3	81.7-93.3	87.5
III	BFG	FH	0.4-13.8	7.1	1.0-12.8	6.9
IV	PS	FH	1.0-16.3	8.6	0.0-21.9	8.3
V	BR	FH	64.9-100.0	83.2	76.5-89.1	82.8
VI	PS	MG	65.5-80.1	72.8	61.5-83.9	72.7
VII	PS	VS	55.7-78.7	67.2	62.0-71.8	66.9
VIII	PS	MS	66.1-82.3	74.2	68.2-80.6	74.4
IX	LS on PS	MG	54.0-71.6	62.8	51.6-72.2	61.9

* BFG Bare frozen ground
PS Packed snow
LS Loose snow
BR Bare roof

** VS Vacuum sweeping
MS Mechanized sweeping
MG Mechanized grading
FH Fire hosing

4. There is no significant difference in the decontamination effectiveness of motor grading on packed snow areas before and after windrow removal.

5. There is no significant difference in the effectiveness of decontamination of a packed snow area among the three methods: motor grading; mechanized sweeping; or vacuum sweeping.

B. Discussion.

Because of the assumed instrument error (±10%), the statistical analysis of the field data resulted in large confidence ranges. If this same data had been obtained from a hypothetical "perfect" meter, the ranges would have been even larger and due singly to variations in decontamination effectiveness. It is more probable that the actual instrument error is larger than the assumed value and the true variations of the decontamination percentages are smaller than those presented in this report. As analyzed in this report, the true mean percentages of decontamination has an 80% chance of being within the given ranges.

It may be noted from the experimental results that the two decontamination percentages calculated for each test have nearly identical means but slightly different ranges. It is necessary, therefore, to prescribe the use of each. The total area mean and range of percentages should be used only for comparison of tests with similar parameters, such as area size, instruments, and methods. In other words, their use is restricted to the comparison of tests in this series. The position by position (pairing observations) values can be used, within limitations, for comparison with results of other tests and for possible extrapolation of results to large or infinite areas.

The test results can be compared with previous work under temperate environmental conditions performed by USNRDL. The use of mechanized sweepers and vacuum sweepers on soil and snow is unique in this Project; therefore, only a very general qualitative comparison can be made to sweeping at temperate-weather conditions. The following is a comparison of McCoy I data with USNRDL data from Stoneman II:[21]

Test	Surface	Sweeper type	Decontamination %
Stoneman II	Asphaltic concrete	Mechanized	92
		Vacuum	99
McCoy I	Bare frozen ground	Mechanized	87
		Vacuum	92
	Packed snow	Mechanized	74
		Vacuum	67

It should be noted that contaminant particle size, relative effort, machines used, and mass deposit levels were somewhat different in the two operations. It can be seen, however, that under cold-weather environmental conditions, the effectiveness was less than that for dry pavement.

The basic recovery manual,[24] TM 3-225, presents an effectiveness of 93% motor-grading soil. Under ideal soil conditions, the effectiveness can rise to 97% as previously reported.[22] When used for plowing snow in this operation, the effectiveness of motor grading was from 63% to 73%. Such plowing was observed to pack the snow as the blade passed over this compressible material. This could account for the lessened effectiveness. A more critical evaluation of the moldboard leading-edge angle to minimize this effect would appear to be in order for future work.

Fire hosing of the asphalt shingle roof would be expected to have a temperate-weather effectiveness of 96% to 98% based on earlier data.[23,24] The test result of 83% is slightly lower but is, nevertheless, an effective figure for many situations. No freezing of water was noted on the roof; in fact, the runoff was free and the roof dried in a few hours of sunlight.

Radiation dosage was kept to a minimum by the experimenters and no residual dosage problems were encountered (see appendix E). Normal camp activities were resumed 30 days after the conclusion of the testing period.

IV. CONCLUSIONS.

The following evidence, based on the fragmentary information obtained during this test series, should be considered tentative and subject to change.

1. The possibly unique decontamination technique of water hosing packed snow and frozen soil is apparently without merit.

2. Mechanized sweeping and vacuum sweeping of packed snow and frozen soil are effective decontamination techniques.

3. The decontamination techniques of grading, sweeping, and hosing on applicable cold-weather surfaces are less effective than the same techniques on corresponding temperate-weather surfaces.

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APPENDIXES

APPENDIX A

COLD-WEATHER BACKGROUND DATA

I. INTRODUCTION.

TM 3-225[1] presents methods and data necessary to perform decontamination operations on fixed military installations. As previously mentioned, these methods and data are based on contamination and decontamination under temperate weather conditions. Certain sections of this manual, such as radiological defense concepts, estimating processes, and methods of recovery planning, will not apply to cold weather operations. The application of basic recovery criteria will have to be modified, however, and in some cases alternate methods will have to be employed. A cold weather addendum to TM 3-225 would present the necessary technical information so that responsible personnel may estimate the recovery effort (in terms of personnel, materials, and equipment) and the over-all effectiveness of various recovery methods under cold-weather conditions.

II. PROBLEM AREAS.

A study has been conducted by this Laboratory of the phenomena associated with cold-weather conditions and their expected effect on decontamination recovery operations. As a result of this study, certain problem areas have been highlighted. The most significant of these, relating to the cold-weather recovery problem, are listed below. It is concluded that the information most urgently needed for a cold-weather addendum to the recovery manual will be met by pursuing a program that includes these problem areas.

A. Human Engineering.

Exposure of personnel to cold weather will necessitate the physiological adjustment of body functions. Use of heavy winter clothing and other essential, but uncomfortable items, may lower the nominal work output expected of a person.

The metabolic cost of performing various grades of work has been investigated by the U. S. Army Quartermaster Corps. Test results are based primarily on treadmill experiments. Figure A-1, taken from previous data,[2] shows the length of time that various grades of work can be continued by young healthy men. These data are group averages and great deviations can be expected for individual instances; however, they provide guidance for application to cold-weather work. It is reported that the metabolic cost, as shown in figure A-1, will be increased by 20% when wearing arctic clothing.

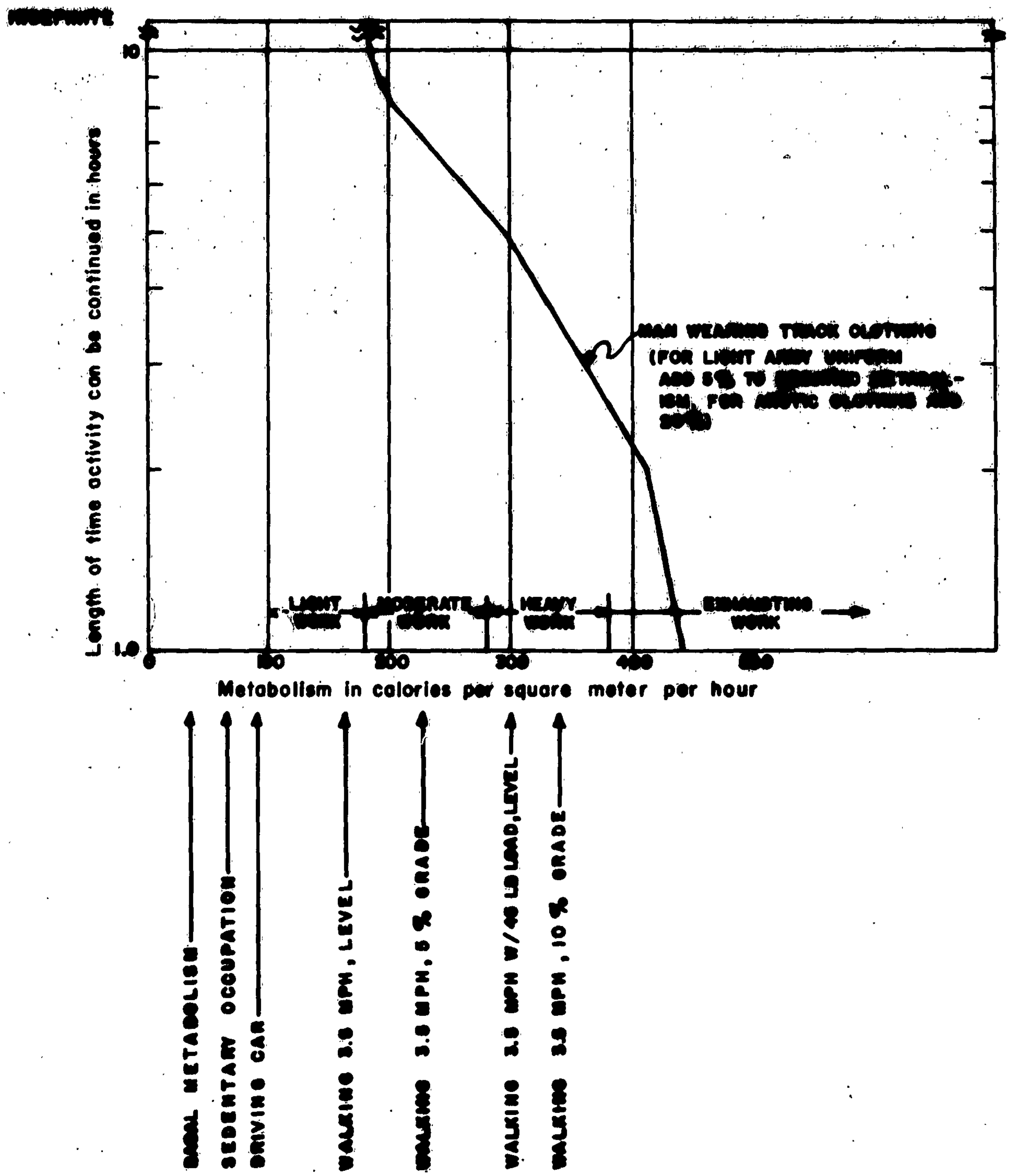

FIGURE A-1

ENDURANCE TIME FOR WORK OF AN ACTIVE MAN
20 TO 30 YEARS OF AGE IN GOOD PHYSICAL CONDITION

Dr. F. N. Craig, of the Physiology Division, USACRDL, has estimated that radiological recovery effort falls into the category of moderate work. Examination of figure A-1 shows that moderate work can be continued for a 4-hr shift even after allowing for the 20% metabolic increase caused by the wearing of arctic clothing.

Exposure of personnel to below-freezing environments can be a limiting factor in a recovery effort. Temperature, wind, and solar radiation are the prime factors affecting cold sensations. The effects of temperature and wind have been combined into the empirical windchill formula which has been correlated with comfort sensations at various levels of windchill.[3] The effect of solar radiation is to decrease the windchill index value by about 200 kg cal/sq m/hr. Although windchill is based on the cooling of naked bodies, the comfort sensations of the clothed body follow the index fairly well, since the face area is always exposed.

Figure A-2 shows a plot of windchill values for various temperatures and wind speeds. The value of 1000 corresponds to a "very-cold" sensation. It is also described as "pleasant conditions for travel (in Antarctica) cease on foggy and overcast days." A value of 1400 is considered dangerous as "freezing of human flesh begins."[3] Since travel in Antarctica is judged to be moderate work, the Windchill Index of 1000 (1200 on sunny days) is probably the upper practical limit for decontamination work. At -10°F, the corresponding wind speed for this condition is only 2 mph; however, this is mitigated by the fact that "lowest temperatures in any locality always occur with calms or very light winds."[4] In any instance, operations inside closed cabs of vehicles would be feasible at -10°F and operations in the open highly probable, provided that the proper type of clothing is worn.

B. Equipment Engineering.

With proper procedures, mos engineering-type equipment, both military and civilian, can be operated in cold weather. The work output of this type of equipment will be adversely affected, however, by various cold weather extremes; i.e., deep snow, frozen ground, thawing ground.

There is little problem in the operation, per se, of earthmoving and engineer equipment in cold environments. Obvious precautions, such as the use of proper grades of lubricants and operation of pumps and hose lines to prevent freezing, must be followed. There are reductions in efficiency, however, in the output of some machinery that are dependent upon such factors as depth of frozen ground for earthmoving equipment, the presence of liquid water on surfaces at temperatures near the thawing point that would make dry sweeping inefficient, and the decrease of operator dexterity when wearing winter clothing. These limitations apply to any construction-type work under cold-weather conditions.

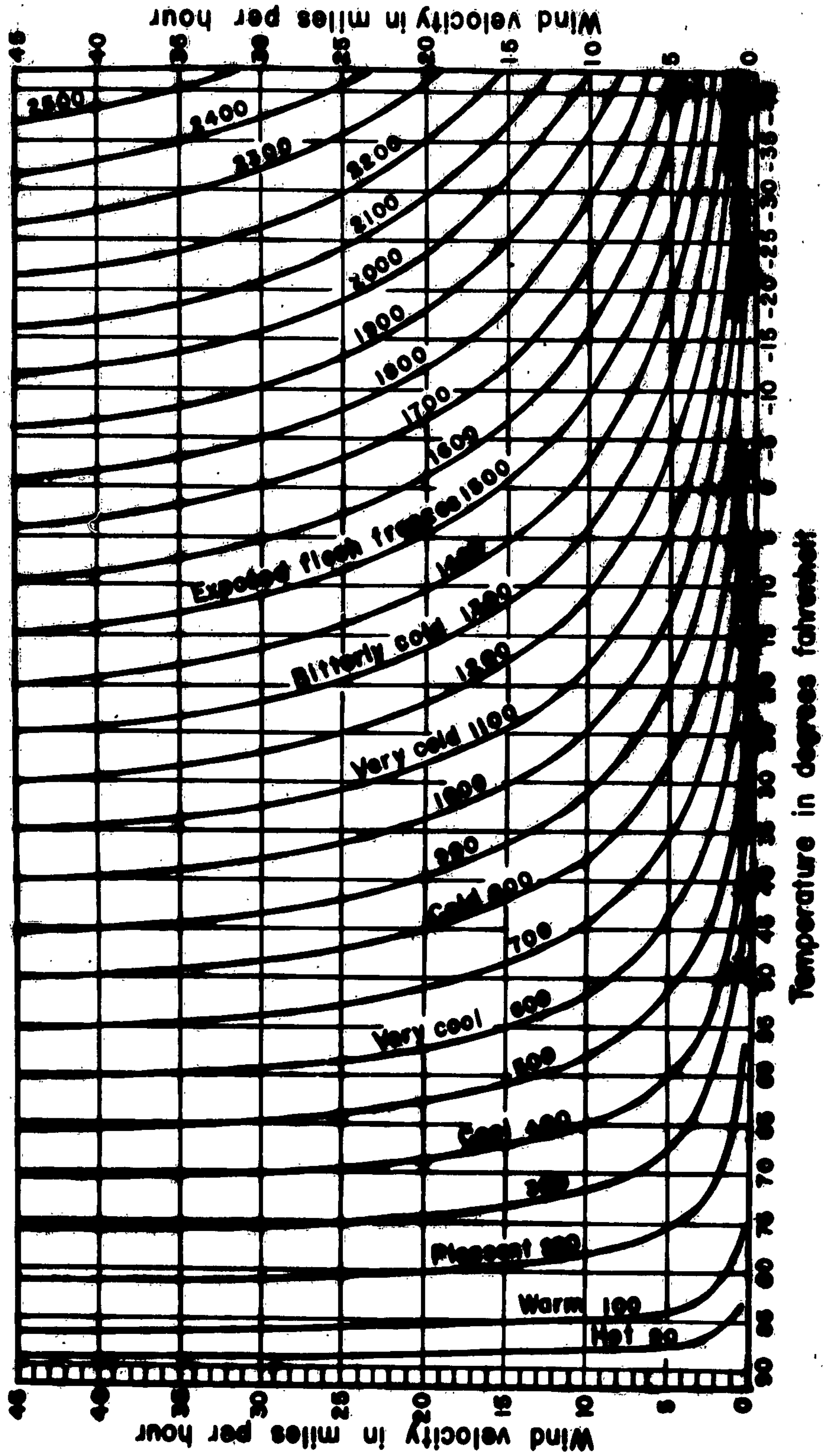

FIGURE A-2

WINDCHILL INDEX

The contamination of engineer equipment during operations in a contaminated area has not proved to be a military problem under temperate conditions. Wet snow will pack on the track, suspension, idler wheels, and sprockets of tracked vehicles. This requires occasional halts to remove the accumulation.[5]

The Naval Civil Engineering Laboratory (NCEL) is currently investigating the decontamination of vehicles under freezing conditions. Cold-chamber facilities at Port Heuneme, California, are being utilized. A newly developed non-leaching fluorescent simulant is used as the contaminant, and field expedient decontamination measures are featured.

C. <u>Water Flow.</u>

The possibility exists that runoff water from hosing operations may freeze, thus concentrating the contamination contained in this water. The parameters affecting the freezing of this runoff water for various temperatures and types of terrain are undefined.

The behavior of runoff water from fire hoses used in decontamination operations, down to temperatures as low as -10°F, is a major problem. It was observed during the recent Fort Greely and Point Barrow, Alaska, tests that at 32°F runoff water ran freely down slight slopes. Under the worst drainage condition, where the runoff was on ocean ice, visible crusting was noted 15 min after stagnation at an air temperature of 7°F and a Windchill Index of 1200. Most fixed installations have well-drained surfaces, at least around buildings, so that runoff water should reach a drain within a few minutes; however, the factors that control the freezing of running water are not well defined. Variables include initial water temperature, water film thickness, air temperature and windspeed (windchill), surface temperature, slope, and solar radiation.

The NCEL is also conducting studies in their cold chamber on the freezing time of water film at various cold environmental conditions. Although the experimental effort is directed toward the requirements of building washdown systems, the data should be applicable to the runoff of hose streams.

D. <u>Fallout Migration on Snow.</u>

Any migration of fallout on snow, either horizontal or verticle, will have a pronounced effect on the decontamination procedure to be used.

The vertical movement of deposited solid fallout into the ground is negligible under temperate conditions, and a similar circumstance would be encountered when the ground is frozen; however, the fallout may settle through snow and ice by a combination of gravity

and thermal action. Since the location of the fallout, with respect to snow or ice surfaces, will determine the decontamination procedure to be followed, it is necessary to understand the phenomena associated with fallout migration.

The NCEL has reported that sand deposited on snow migrated a maximum vertical distance of 1-1/2 in. until solar radiation no longer had an effect. Little else is known of this phenomenon.

The movement of contaminant by wind under drifting snow conditions may materially alter the initial fallout pattern, as contrasted to the situation where the snow is crusted. The formation of "hot spots" on the leeward sides of buildings, embankments, etc., may be expected. This effect and possible decontamination implications have not been studied.

E. Dose Factors.

The effect of snow cover on dose rates in the instance of snow fall subsequent to the arrival of contamination must be considered. The dose rate for loads of contaminated snow, important in snow removal procedures, is not defined.

The operators of equipment, such as mechanized scrapers, loaders, and dump trucks, should receive a greater dose from a contaminated load of snow than from a contaminated load of soil. This is due to the lower bulk shielding characteristics of snow as compared to that of soil.

The magnitude of this increased dose has possible significance. In addition, there is the possibility of shielding afforded by snowfall subsequent to a contaminating event.

F. Decontamination Effectiveness and Techniques.

The residual numbers for temperate decontamination operations will require modification for certain cold-weather conditions. Modification or substitution of certain techniques, such as hosing, sweeping, and scraping, will be necessary during cold-weather decontamination operations.

Only limited experimental data have been published on the decontamination effectiveness of any method at low temperatures. The Gordon and Smith report[6] contains some data on the decontamination of tar paper and galvanized iron at 0°F using 8- and 40-psi water hosing. The contaminant was not representative of fallout, but was particulate in nature. For the fire-hosing pressure at 40 psi, there was little difference in over-all effectiveness on originally dry surfaces at 0° and 70°F; however, the effort required increased by as much as a factor of 2 when ice or snow was present on the surfaces initially. At the lower hosing pressure of 8 psi, the effectiveness on tar paper noticeably decreased at the cold condition.

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4. Court, A. Wind Chill. Bull. Am. Meteorol. Soc. 29, No. 10. December 1948.

5. Northern Operations. FM 31-71. January 1959.

6. Gordon, M. G. and Smith, R. J. Classified title. CRLR 571. April 1956.

APPENDIX B

TEST-SITE CRITERIA AND SELECTION

I. TEST-SITE CRITERIA.

To meet the objectives of the Project 4X12-01-001-02, the following criteria, in the order of their importance, were deemed necessary:

1. January mean temperature (from 0° to 10°F) and 1-ft snow cover.

2. Approval to use isotopes and restricted test and operating areas for suitable periods.

3. A test area isolated by a distance of at least 1 mile from inhabited areas, but including paved streets, buildings, electricity, and a water-supply system with fire hydrants.

4. An operations area, including a heated building or buildings for simulant production and a change house.

5. Available logistic support in the form of engineer equipment, maintenance facilities, and shops.

6. Operating motor pool.

7. Housing for test participants.

8. Emergency procurement office.

II. TEST-SITE SELECTION AND DESCRIPTION.

A survey of military installations which could best meet the above criteria, disclosed that Camp McCoy, Wisconsin, was the logical choice. This camp met all requirements except the first; the January mean temperature is 5°F higher than the desired 10°F. It should be noted, however, that the January mean temperature does not go below 10°F at any location in the continental United States where military camps are located. Accordingly, arrangements were made through Headquarters, Fifth U. S. Army for the use of Camp McCoy as the test site.

This camp, originally designed to accommodate a World War II triangular division, is now utilized as the summer training area for Army Reserve and National Guard units in the Fifth U. S. Army. Logistic facilities are on hand for such training, and are available for use

during the remaining period of the year when the camp reverts to inactive status. A map of the camp's cantonment area is presented in figure B-1. It should be noted that during the winter, practically all camp functions are restricted to the area adjacent to or south of Tarr Creek, leaving vast areas in the northern part of the camp available for radiological test work.

Figure B-2 is a map showing blocks 1 through 6 of Camp McCoy that were selected as the operations and test areas.

Building 37 was selected as the location of the fallout simulant processing facility. It has a floor area of 40 by 120 ft with an 18-ft high ceiling and double overhead garage doors at each end. In processing the fallout simulant, the raw materials were unloaded in one end of the building, and proceeded in a line from the hot cell, through the various operations, to a bin at the other end.

A change house was established in building 30, a nearby barracks. All cold-weather apparel and protective clothing were kept in this building when not in use. The usual monitoring, showering, and hot and cold locker arrangements were employed. On the second floor of this building was a storage room and a field office.

Laboratory space was provided by the radiochemical trailer, Radiac Set, AN/NDQ-1, parked inside building 47, a vehicle maintenance building. A counting room was located in a small room of this building, and the remainder of the floor area, 30 by 30 ft, was utilized for sand storage, sifting, grading, and bagging operations.

Building 45 was used for storage of hot vehicles when not in use and as a field-area personnel shelter. The only other structure occupied by the project was building 33, an orderly room utilized as an illuminated ambient-temperature instrument calibration range. The roof of building 50 and the parking lots and land areas in blocks 5 and 6 were used as test surfaces.

Final disposal of waste, 1 mo after operations, was made by burial in a pit in the buffer zone to the camp's remote North Impact Area.

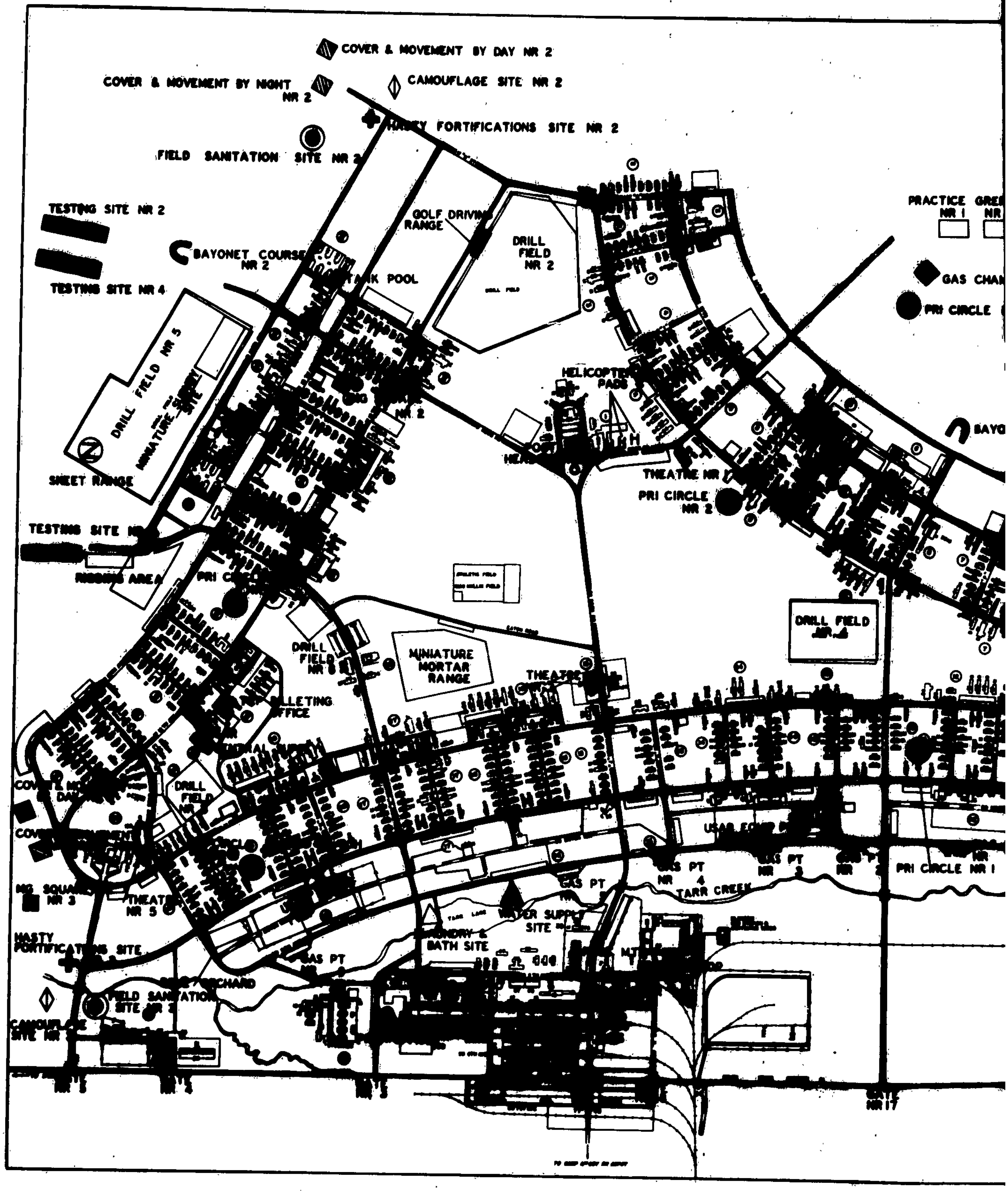
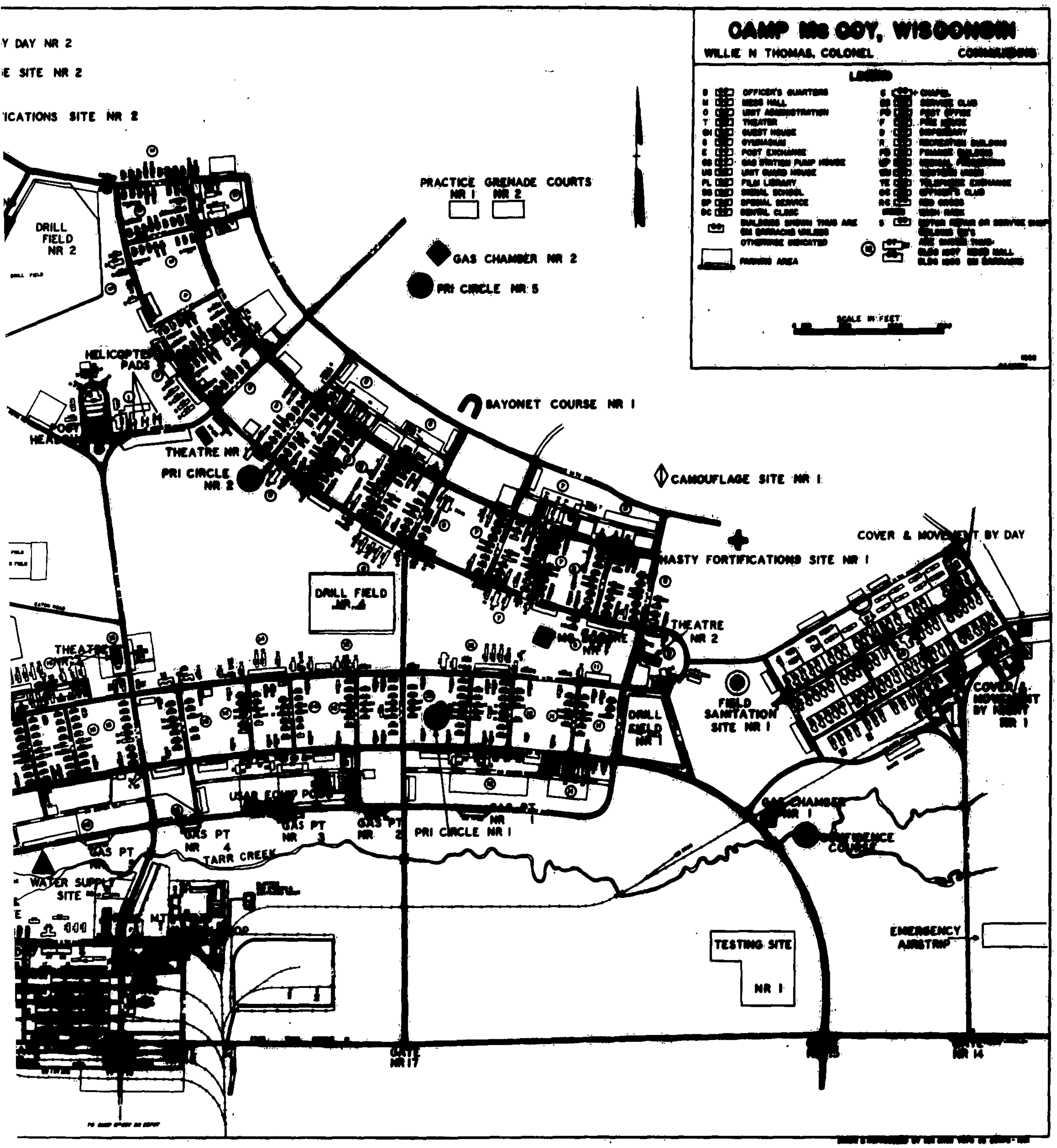


FIGURE B-1

CANTONMENT AND CLOSE IN FACILITIES


CAMP McCOY, WISCONSIN
WILLIE N THOMAS, COLONEL
OFFICER'S QUARTERS
MESS HALL
UNIT ADMINISTRATION
THEATER
GUEST HOUSE
GYMNASIUM
POST EXCHANGE
GAS STATION PUMP HOUSE
UNIT GUARD HOUSE
FILM LIBRARY
SIGNAL SCHOOL
SPECIAL SERVICE
DENTAL CLINIC
CHAPEL
SERVICE CLUB
POST OFFICE
OFFICER'S CLUB
PARKING AREA
SCALE IN FEET
Y DAY NR 2
E SITE NR 2
ICATIONS SITE NR 2
PRACTICE GRENADE COURTS
NR 1
NR 2
GAS CHAMBER NR 2
PRI CIRCLE NR 5
DRILL FIELD NR 2
HELICOPTER PADS
THEATRE NR 1
PRI CIRCLE NR 2
BAYONET COURSE NR 1
CAMOUFLAGE SITE NR 1
COVER & MOVEMENT BY DAY
HASTY FORTIFICATIONS SITE NR 1
DRILL FIELD NR 4
THEATRE NR 2
FIELD SANITATION SITE NR 1
COVER & MOVEMENT BY NIGHT NR 1
DRILL FIELD NR 1
GAS CHAMBER NR 1
GAS PT NR 1
GAS PT NR 2
GAS PT NR 3
GAS PT NR 4
PRI CIRCLE NR 1
TARR CREEK
WATER SUPPLY SITE
TESTING SITE NR 1
EMERGENCY AIRSTRIP
GATE NR 17
GATE NR 14

LITIES

2

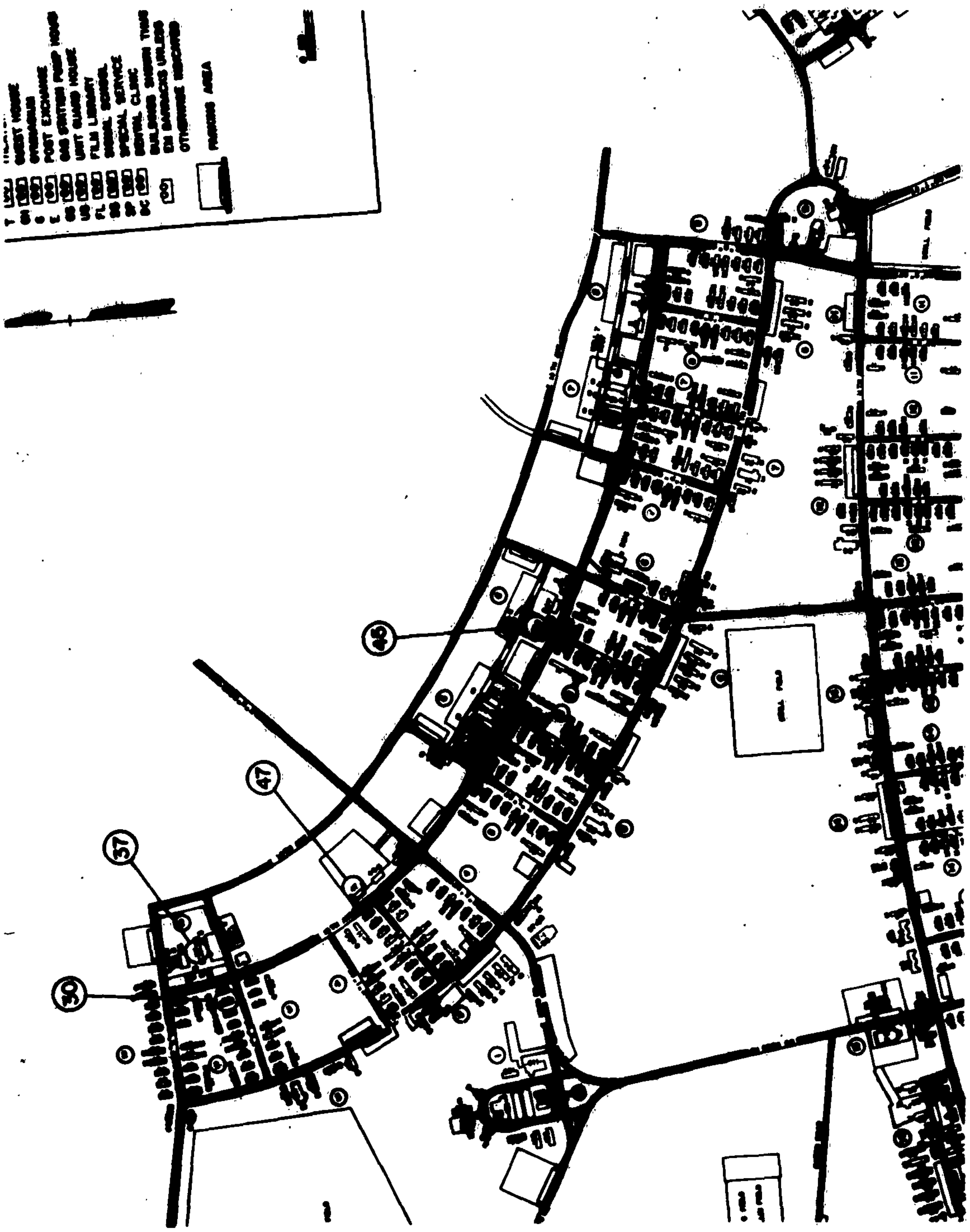


FIGURE B-2

OPERATIONS AND TEST AREAS

APPENDIX C

SIMULANT PRODUCTION FACILITIES AND PROCEDURES

I. PROCESSING.

Figure C-1 presents the flow diagram of the production process and figure C-2 presents the floor plan of building 37, the principal production area. The following is a description of the various steps necessary in the production of the radioactive simulant:

A. Sand Processing.

Portage 515 Silica Sand was delivered to building 47 by the supplier in a tank truck. The supplier's chemical and physical analyses of this sand are tabulated in the table, appendix C. The appearance of the sand is clean, white, rounded particles. The sand was sieved on a Novo, model SS-8, sieving machine (see figure C-3), in order to separate the 150μ to 300μ size fraction. The sieved sand was bagged in 50-lb sacks and transported by fork lift to building 37.

B. Isotope Processing.

Quartz capsules containing 2 gm of La_2O_3 were irradiated as required in the CP-5 nuclear reactor at Argonne National Laboratory (ANL), Lemont, Illinois. Irradiations were performed in a thermal neutron flux of 5×10^{13} N/sq cm/sec in order to produce specific activities in the range of 7 to 13 curies/gm. The capsules were loaded by ANL personnel into a shielding container with 7-in.-thick lead walls, weighing 1850 lb. This was transported by truck to Camp McCoy, Wisconsin, a distance of 275 miles, which required 8 hr of driving time. Upon arrival at Camp McCoy, the truck backed through the west access door of building 37 where the shield was unloaded by a fork lift. It was then picked up by an overhead monorail trolley hoist and transported into the hot cell.

The hot cell was a room 8 ft wide, 12 ft long, and 10 ft high surrounded by concrete walls approximately 2 ft thick. The walls were made of three rows of solid concrete blocks 4 by 8 by 16 in. laid without mortar. They were so stacked that the cracks between blocks were out of alignment. This provided a minimum shielding thickness of 16 in. of concrete. The walls were coated with two coats of whitewash. Special attention was given to thoroughly brushing the whitewash into all cracks. The ceiling of the hot cell was sheet rock with all corners and joints taped and spackled. The double access doors and double monorail-closure doors were tight fitting with sponge rubber seals. Figure C-4 shows some stages of the cell construction.

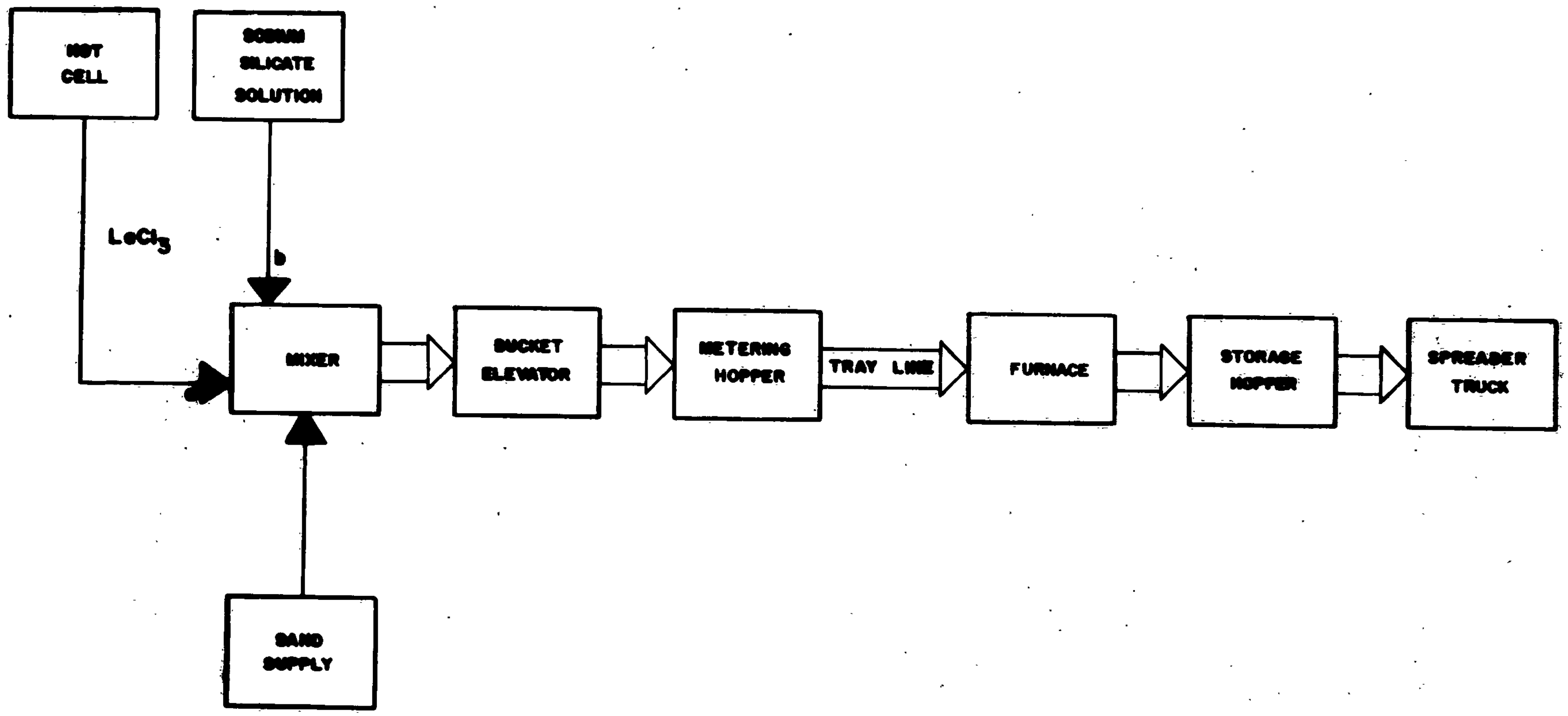


FIGURE C-1

SIMULANT PRODUCTION FLOW DIAGRAM

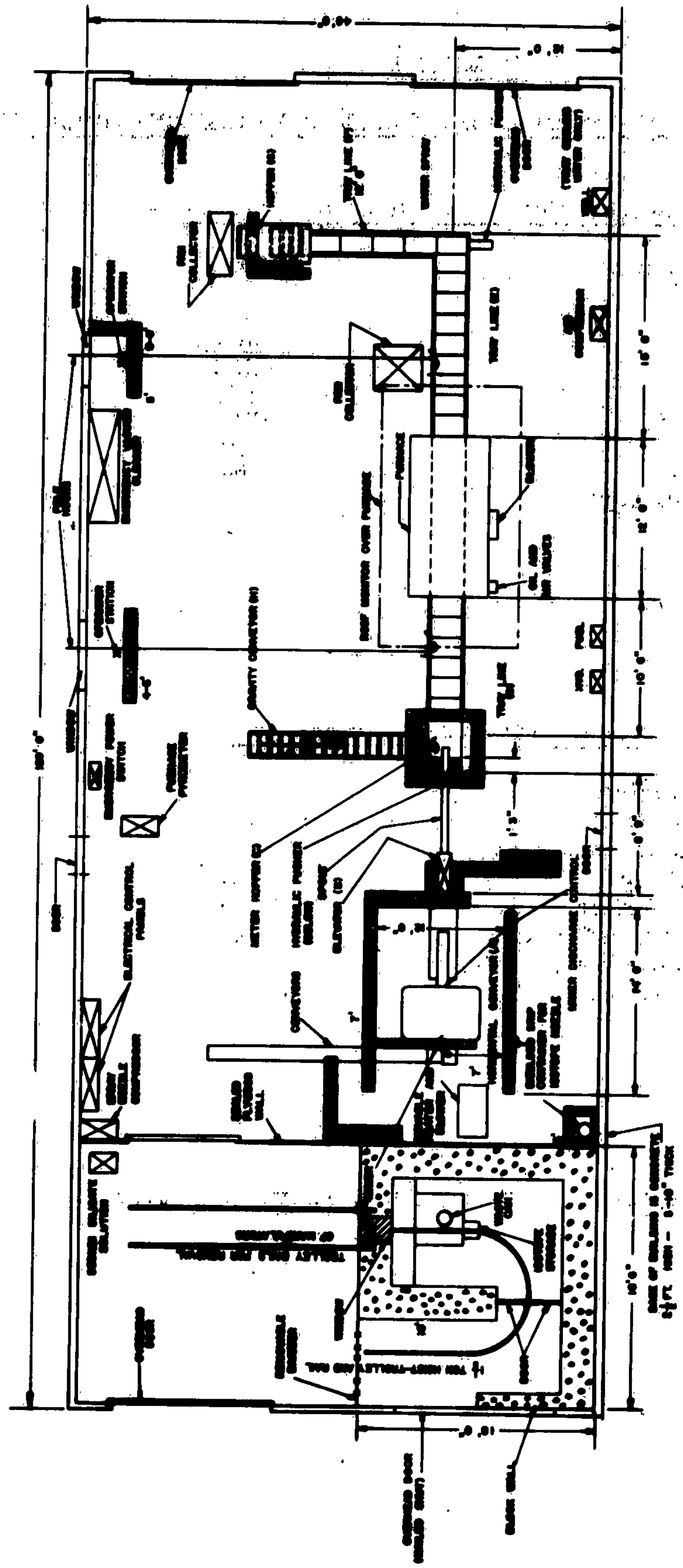


FIGURE C-2

FALLOUT SIMULANT PRODUCTION FACILITY

TABLE C-1

PORTAGE DRIED AND SCREENED 515 SILICA SAND CHARACTERISTICS *

Percentage of Total Sand Retained by Sieves

Sieve size	%
On 40	1.6
On 50	14.7
On 70	31.7
On 100	31.4
On 140	15.1
On 200	4.4
On 270 & pan	0.9

Representative Chemical Analysis

Silica	99.58%
Iron oxide	0.021% - 0.026%
Aluminum oxide	0.20%
Titanium oxide	0.011%
Calcium oxide	0.01%
Magnesium oxide	Trace
Loss on ignition	0.17%
Fusion point	3,050°F

* Supplied by Carpenter Brothers, Inc., Milwaukee, Wisconsin.

FIGURE C-3

SIEVING MACHINE INSTALLATION

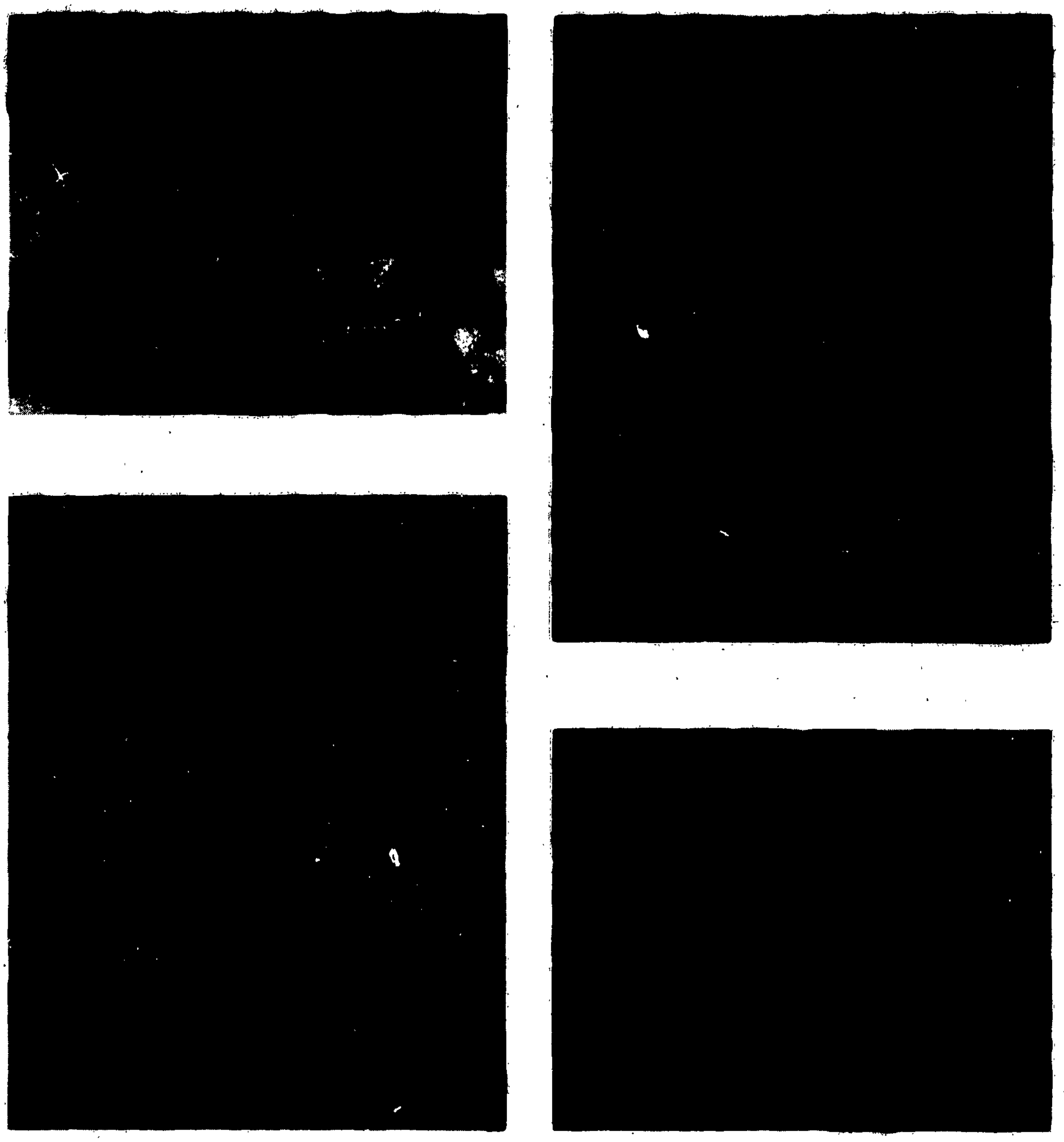


FIGURE C-4

STAGES OF HOT-CELL CONSTRUCTION

A viewing window, 2 by 2 by 2 ft., was placed in the front wall and filled with optical-grade zinc bromide. Also installed on the front wall was a pair of model 8 master-slave manipulators. Figure C-5 shows the operator using manipulators to prepare materials for a production run. To the left of the viewing window was an access tube of 2-in. pipe used for sampling; when not in use, the end was capped with a 4-in.-long lead plug.

A 9-in. monorail beam was mounted inside the hot cell and was equipped with a 2-ton trolley chain hoist. A 30-in. platform was provided in the cell on which to place the lead shield.

Two stainless steel trays covered the tables on which the chemical work was performed. One tray was 2 by 8 ft and had a 1-in. lip. This tray was used for storage of mirrors and cold chemicals. It was placed directly in front of the hot-cell window and was supported by sawhorses. The other tray was a square hot-work table with 4-ft. sides and a 2-in. lip. It was supported by a plywood box filled with sand that was used to shield a dry wastebasket located below a hole in the center of the tray.

The cell was equipped with electrical outlets and vacuum and pressure lines. Each vacuum line was equipped with a trap to prevent pulling radioactive material from the cell. A hot plate was located on the work table to heat the lanthanum solution. A mechanical device used to fracture the quartz vials was located on the storage tray. The glassware used in dissolving the samples consisted of a 400-ml beaker, a 250-ml volumetric flask, a 250-ml graduated cylinder, a filter tube with 30-mm diameter fritted filter, and a 1-liter jug with a manifold and necessary stopcocks to permit evacuation, pressurization, or flushing of the jug. A Tygon tube was connected to the discharge tube of the jug to permit transfer of the solution to the mixer. The interior of the hot cell is shown in figure C-6.

An exhaust fan, capable of moving air at the rate of 500 cfm against a pressure differential of 0.5-in. water, was connected to the hot cell by the way of duct work and a filter system to an exhaust stack outside the building housing the simulant production facility. The filter system for the hot cell consisted of four coarse filters in series and two fine filters in parallel. The coarse filters were furnace-type. They were 25 by 25 by 2 in. and were capable of handling 1,000 cfm at a pressure differential of 1-in. water. The fine filters, CWS absolute type, manufactured by the Cambridge Filter Corporation of Syracuse, New York, provided an airflow cross section measuring 24 by 48 by 11.5 in.

In the hot-cell operations, the monorail hoist hook was engaged to the shield cover and all personnel withdrew from the hot-cell interior. The warning devices were activated to set an alarm when any

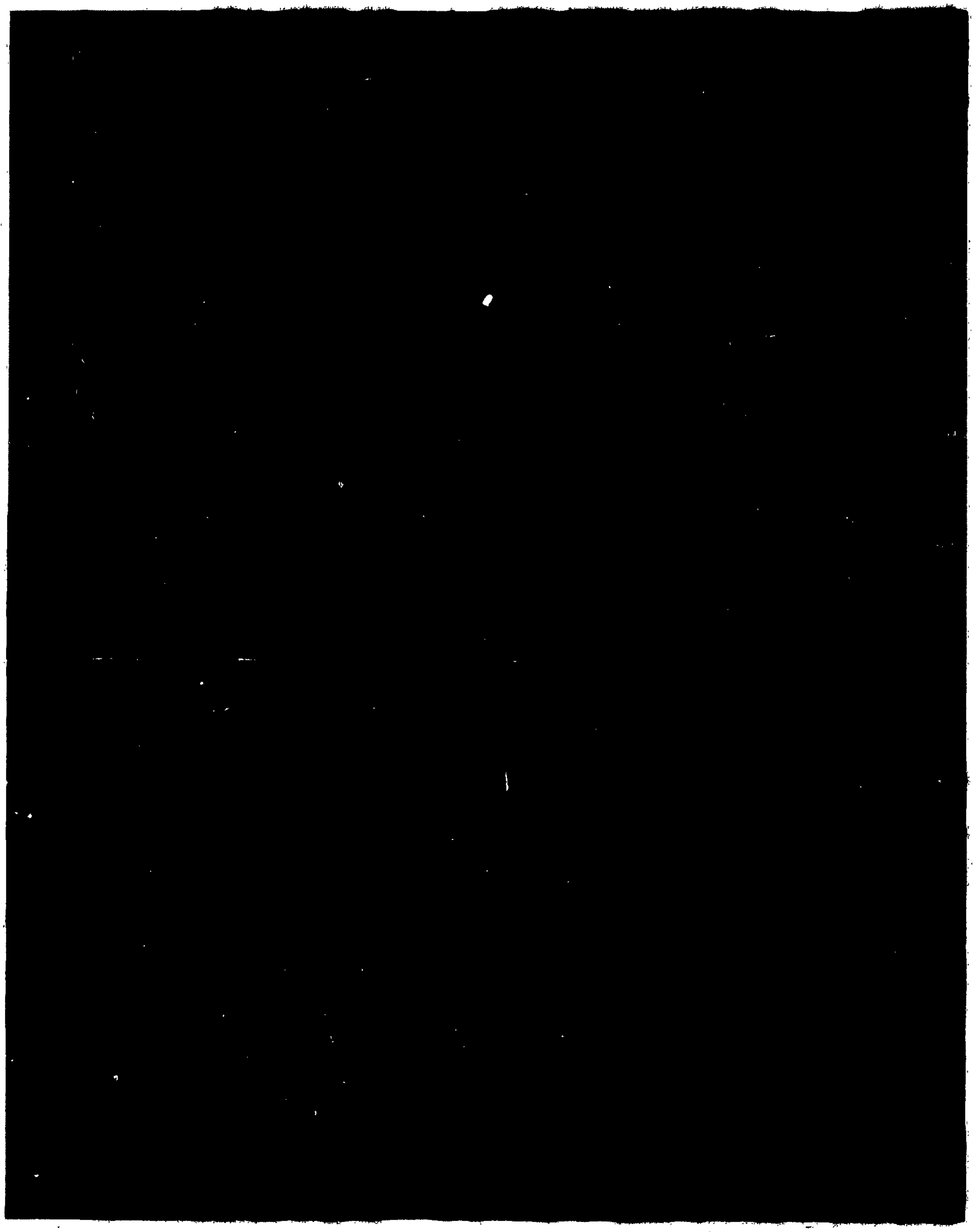


FIGURE C-5

USING MASTER-SLAVE MANIPULATORS
DURING PREPARATION OF $LaCl_3$ SOLUTION

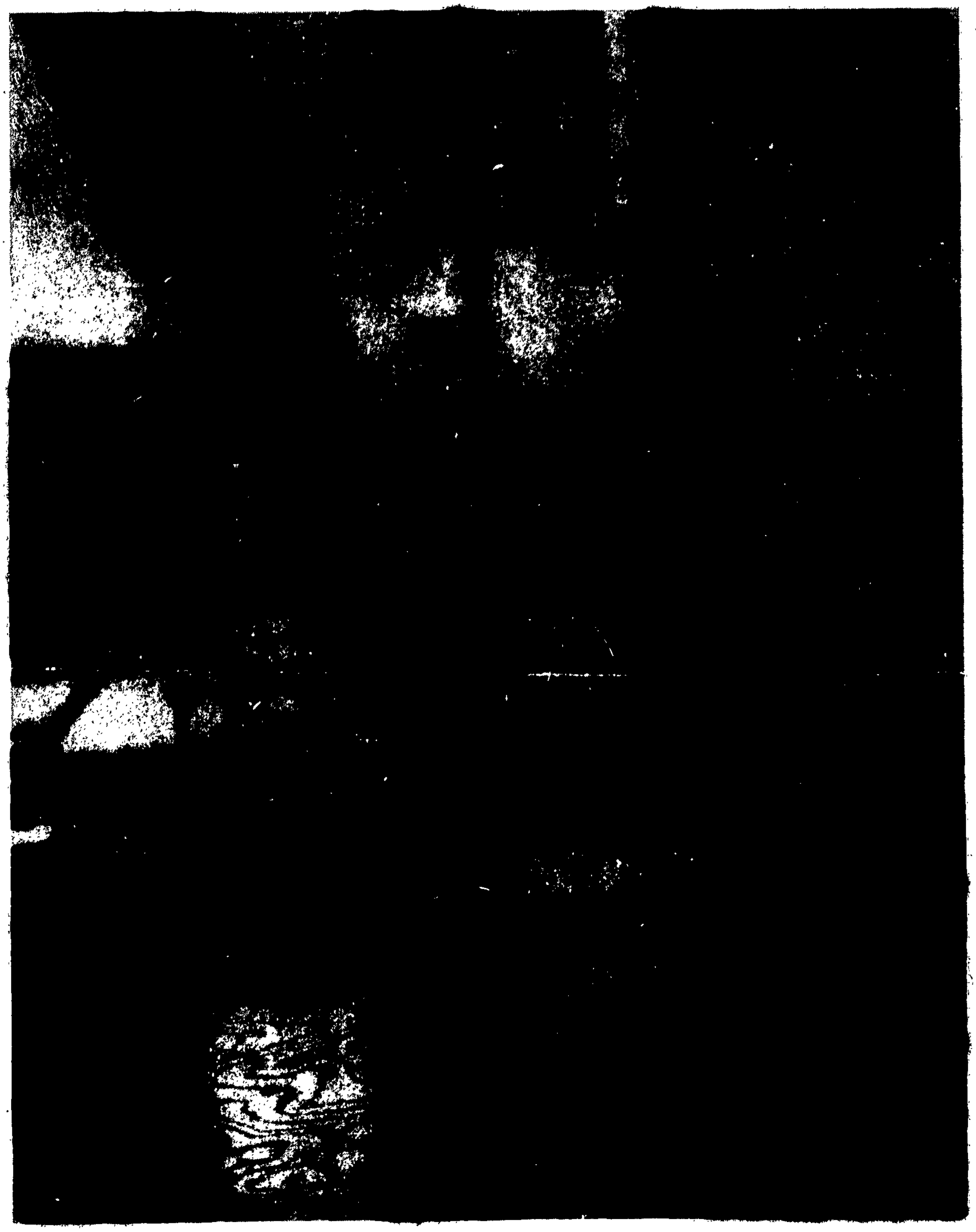


FIGURE C-6

HOT-CELL INTERIOR

opening of the hot-cell access doors occurred. All hot-cell operations were performed by the hot-cell operator from outside the cell using master slave manipulators, and insertable sample receiving tube, and utility controls. The shield cover was removed by the hoist, and the capsule container removed from the shield by locating and pulling out a leader wire with the manipulators. This wire was attached to an aluminum container, which was opened by breaking a wire seal. The quartz capsule containing the isotope was taken out, the foil wrapper removed, and the capsule placed in the jaws of the crushing device. This was then placed in a 400-ml beaker of warm 0.1 N hydrochloric acid. Tightening the thumb screw on the crushing device fractured the quartz, allowing the radioactive La_2O_3 to dissolve in the acid producing a solution of $LaCl_3$. Dissolution was hastened by transferring the beaker to a magnetic stirrer.

A 1-ml sample of the solution was prepared for activity assay. This was done by taking a 200-λ sample and diluting it in 250 ml of water in a volumetric flask. The 1-ml sample was withdrawn and placed in a 10-ml beaker in the end of the sample receiving tube, which was pushed through the access tube in the cell wall. This sample was removed from the hot cell and transported to building 47 for counting, to determine the specific activity. Then an amount of the radioactive solution, calculated to contain 5 curies, was poured and measured in the graduated cylinder. This was then transferred, by vacuum, to the collecting jug, through the fritted filter, and diluted with water to provide 400 ml of solution for the next operation.

II. SIMULANT MIXING.

Mixing of sand, isotope, and sodium silicate was done in 500-lb batches in a modified, trailer-mounted, 16-cu ft concrete mixer. Modification included adding internal heating elements and extensions to the mixing blades, and replacement of both doors with special air-tight doors. One door contained a vent pipe for connection to the exhaust system, a slotted pipe that served as a receptacle for the nozzles and air heater, and a small covered feed hatch. The second door had an attached dumping chute that was remotely inserted into the mixer. The mixer was equipped with outrigger legs for support during operation. The mixer exhaust system was identical to that of the hot cell.

Accessory equipment included an inlet air heater and blower, an inclined belt conveyor and funnel for loading the mixer, and a similar conveyor to convey discharged sand from the mixer to the bucket elevator. This inclosed elevator elevated the sand so that it was discharged into the metering hopper through a round spout. Both ends of the mixer are shown in figure C-7.

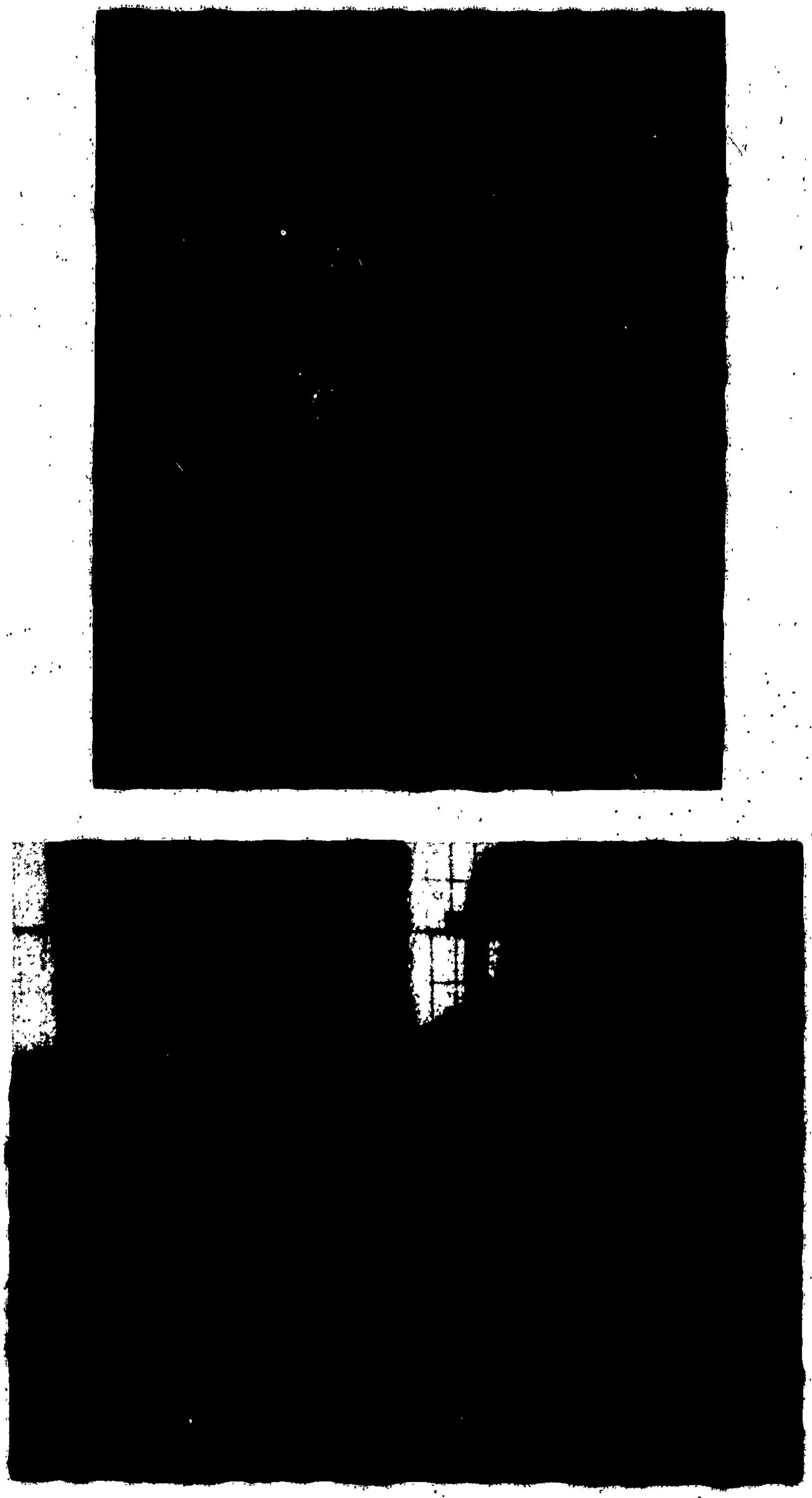


FIGURE C-7

MIXER

a. Input Side
b. Discharge Side

Two spray lances, an isotope lance and a silicate lance, were separately used in conjunction with the mixer. The lance was mounted in the mixer bowl along the axial centerline. Each lance had two supply tubes, one of which was the atomizing air line. On the isotope lance there was a Tygon tube connected to the isotope jug in the hot cell. The silicate lance was connected by a hose to a 4-in. diameter glass pipe used as the metered silicate supply. The lances were secured in place on the mixer by snapping two suitcase latches. When not in use, the lances were stored in shielded drip pans. For details of these features, see figure C-8.

In operation the sand was loaded into the mixer and preheated for 1 hr. The isotope lance was mounted in place and the 400 ml of $LaCl_3$ solution sprayed into the revolving mixer drum. Transfer of isotope from the hot cell to mixer was done by pressurizing the isotope jug with 15-psi nitrogen, forcing the solution through the connecting Tygon flexible line. This line was then rinsed by passing through 200 ml of water. Next, the isotope lance was removed and replaced by the sodium silicate lance. Five liters of 19% sodium silicate were sprayed into the drum to coat the tagged sand particles, and the line was then flushed with 1 liter of water. The silicate lance was removed and replaced by the nozzle of the portable air heater. The mixture was then allowed to mix and dry for 2 hr. At this time, a trip on the dump chute was triggered remotely, inserting this chute into the mixer by spring action. The conveyor and bucket elevator then transferred the simulant to the metering hopper.

III. <u>CONTAMINANT FIXATION</u>.

The final process in the simulant production was baking the coated sand at 1,000°C for 1 hr in order to fuze the sodium silicate. This involved loading the sand into six pans of 42 lb each to make up a 250-lb batch in the baking furnace. Two such batches constituted a 500-lb production run. Following baking, the pans of sand were cooled and delivered to a final portable hopper.

The metering hopper was a dual hopper that dispensed a fixed amount of sand into each pan. The 500-lb capacity upper hopper received sand from the bucket elevator discharge spout. Directly below the upper bin was a mechanism with two remotely controlled pneumatic-powered slide gates. Opening and closing the upper slide allowed 42 lb of sand to fill the lower hopper. A pan on the tray line below this lower hopper was filled by manipulation of the lower gate. The dual hopper is shown in figure C-9.

Accessory equipment included a gravity-feed roller conveyor to support and supply pans, a remotely controlled hydraulic pusher to move filled pans, and a rail-tray line for the movement of filled pans to the furnace.

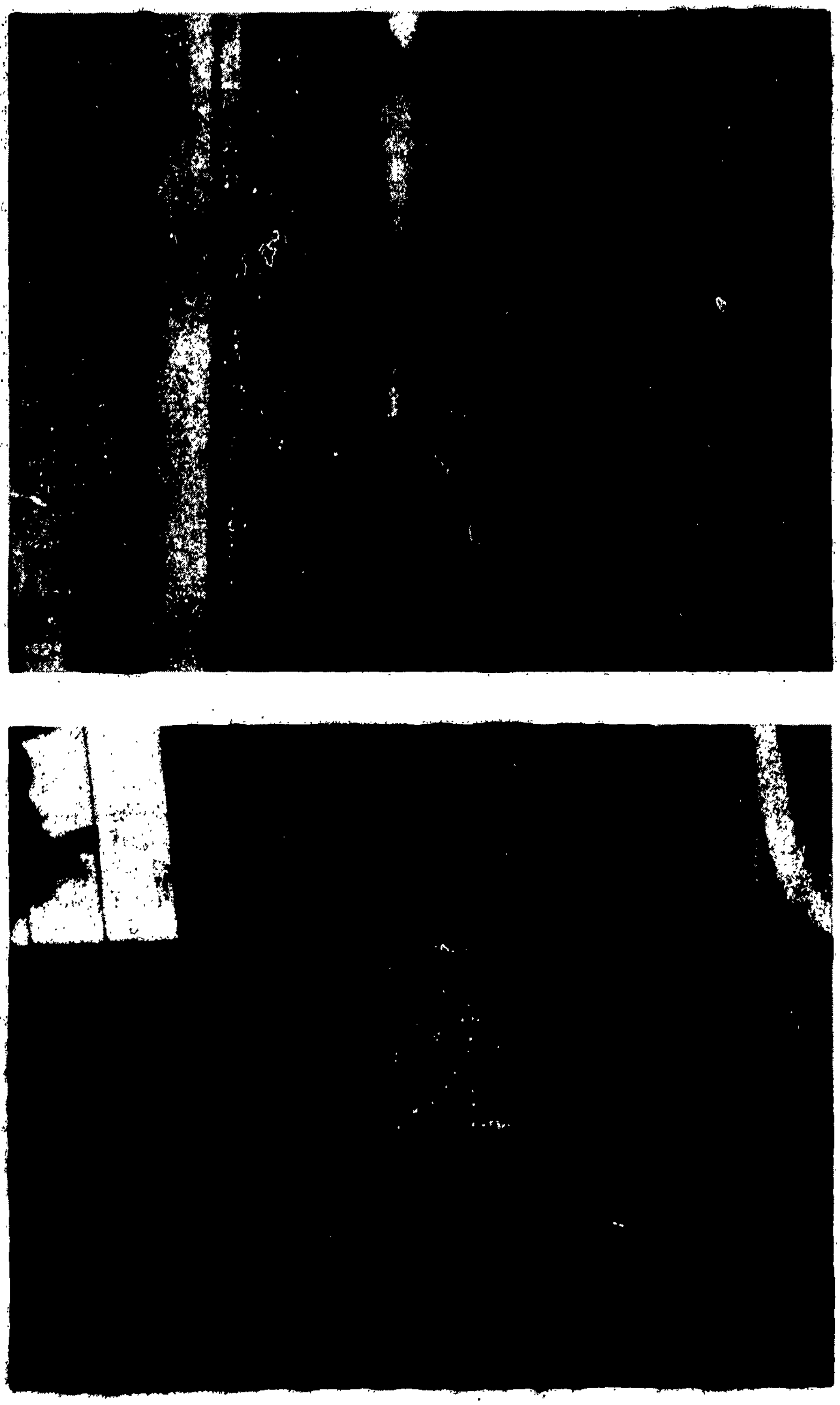


FIGURE C-8

LANCE OPERATION (PRACTICE RUN)

a. Inserting Lance Into Mixer
b. Storing Lance in Drip Pan

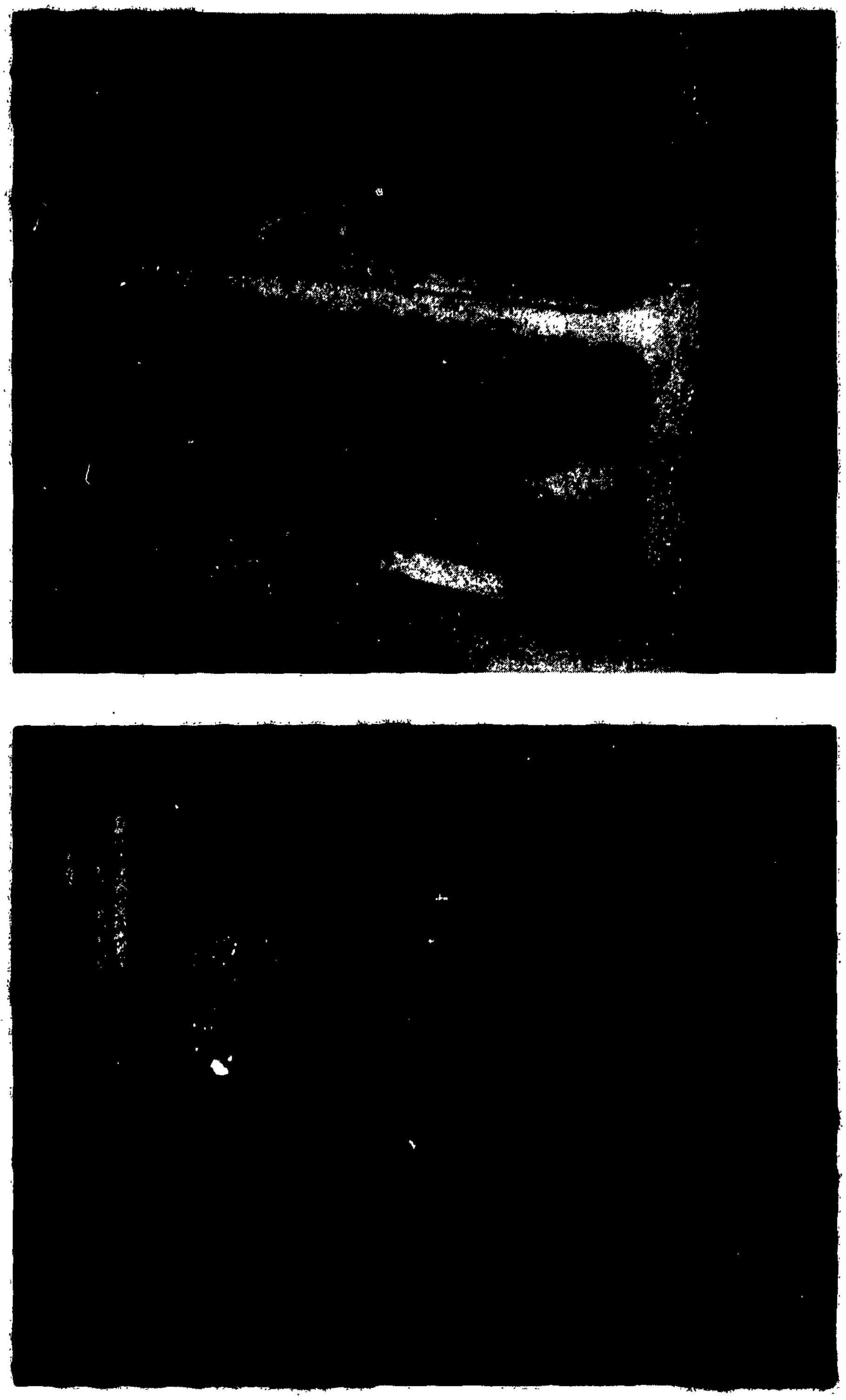


FIGURE C-9

METERING HOPPER

a. Showing Pneumatic Cylinder Actuators
b. Position of Hopper in Relation to Furnace

The furnace was a hearth area box, open at both ends, with over-all dimensions of 14 by 4 by 10 ft that weighed 15 tons. Into the bottom of the hearth were inserted three carbofrax skid rails. The heat was furnished by six diesel oil burners. The fuel was atomized by air supplied by a compressor at 90 psi at a rate of 40 cfm (std.). Combustion air was supplied by a 2 hp blower operating at a 9-in. water-gage pressure. Venting of combustion gases was accomplished by a hood canopy and a sheet-metal chimney with a 14,000-cfm coaxial blower in the chimney duct. The furnace with the exhaust hood is shown in figure C-10. The doors at each end were permanently kept open to permit the exhausting of combustion gases and the entering and discharging of pans being processed. The furnace was lined with refractory brick and had a sprung-arch roof. The temperature was controlled by means of a thermocouple and a solenoid-operated fuel valve.

At the end of the production line was a hopper into which all processed sand was dumped. This hopper was located at the top of the final incline of the rail-tray line. As the pans were pushed past the end of the incline they were tipped forward, and then overturned by the following pan. This dumped the sand into the hopper, with the overturned empty pans being retained by a gravity-roller conveyor. Figure C-11 illustrates this operation. The bottom of the hopper was equipped with a small roll grinder under which was accommodated a portable hopper used for loading the spreader truck. A mechanical, remotely controlled gate was provided at the end of the roller conveyor to control the passage of empty pans.

The extreme heat of the pans and their contents and the insulating qualities of the sand made it imperative that cooling of the sand be accelerated. This was accomplished by drilling a well at the east end of building 37 to provide a source of water that would spray on the underside of the pans as they came out of the furnace. The pans were sprayed until the sand was dumped into the hopper at the end of the line.

IV. FINAL CONTAMINANT HANDLING AND SPREADING.

The final hopper in the production line, containing 500 lb of simulant, was manually pulled from building 37 by a 15 ft long pole hook. It was then picked up by a shielded fork-lift truck and maneuvered so that the loaded hopper was located above the bin of a Burch Hydron sand spreader mounted on a 5-yd dump truck. The operator dumped the simulant into the spreader bin by activating the release mechanism with the long pole hook (see figure C-12). The truck was then driven to the test area.

The sand spreader is a commercial unit, with a friction power take-off from the truck's rear wheels. It is designed to uniformly

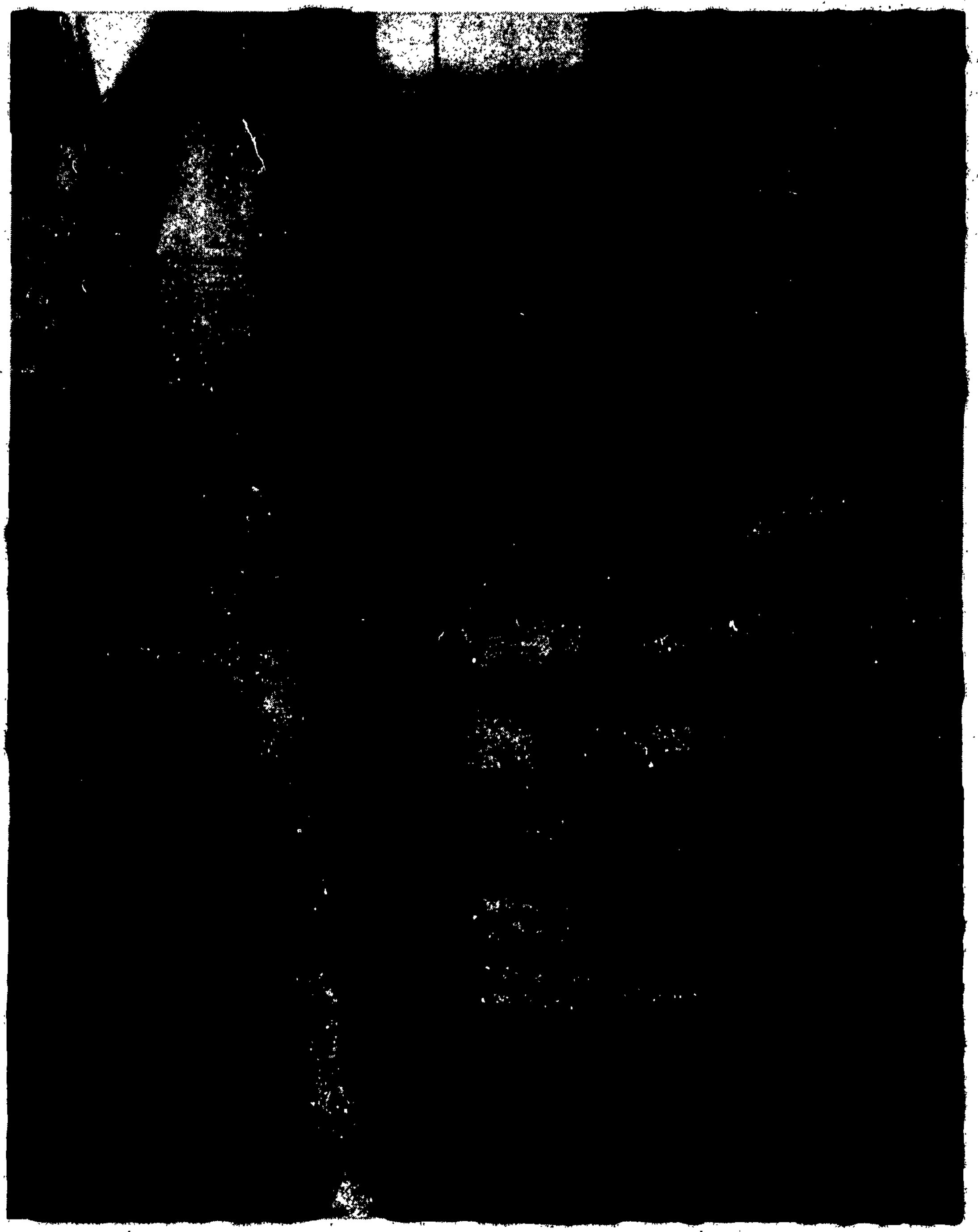


FIGURE C-10

HIGH TEMPERATURE FURNACE AND HOOD

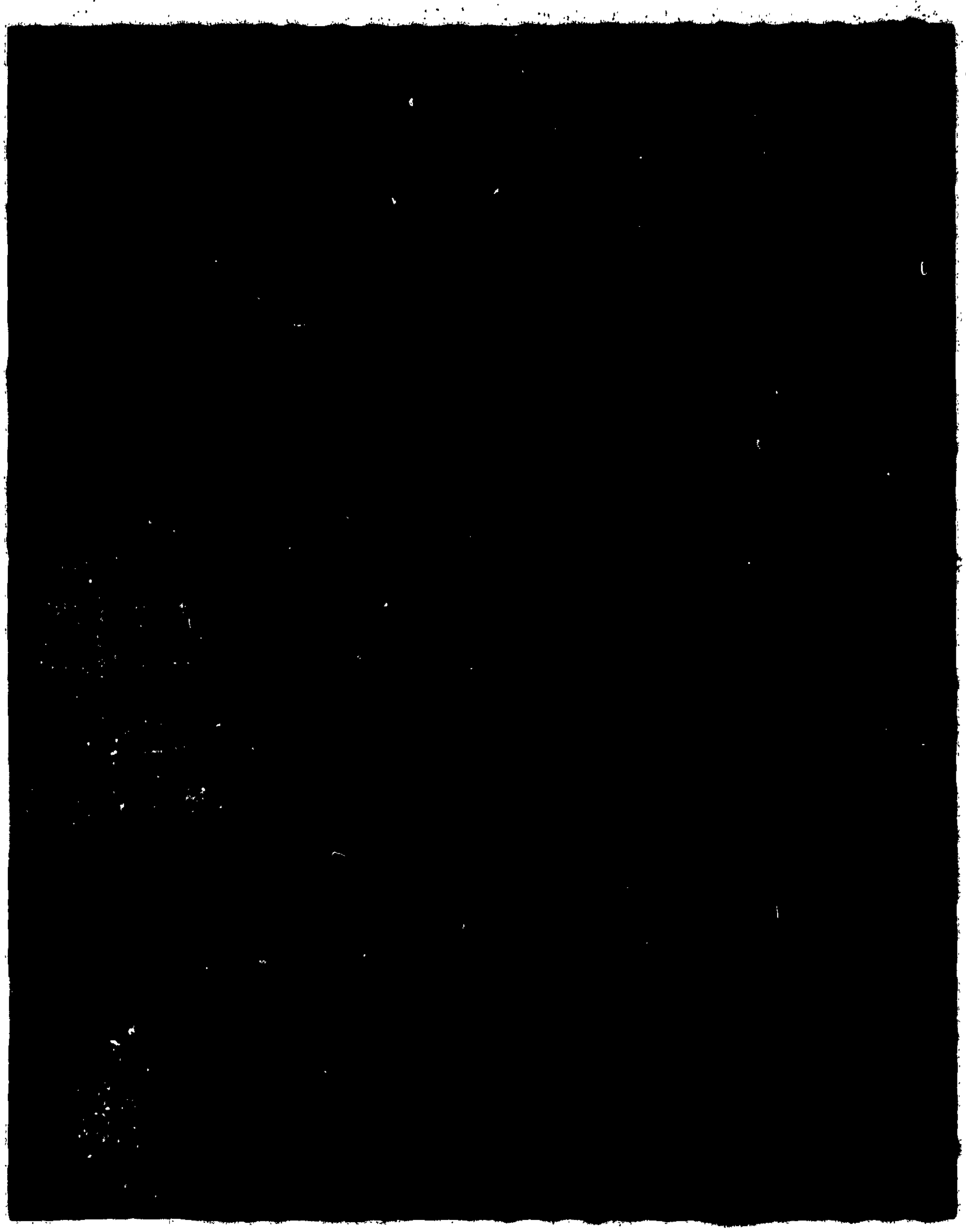


FIGURE C-11

EMPTYING PANS OF PROCESSED SAND

spread road surfacing and antiskid material. Uniformity was enhanced by adding an extension trough at the outlet end to smooth-feed variations caused by material delivery splines, and to limit the free fall of material to 2 to 3 in. when the truck bed is raised (see figure C-12). The model used spread a path of nominal 7 ft width. In practice, three passes produced a 20-ft wide contaminated strip. Operationally, the truck was driven at a crawl, with power take-off engaged before starting, to minimize slippage of snow or moisture-coated friction drive wheels.

In the roof test, a 2-ft wide Scott lawn spreader was used. This was modified to include a 10-ft long handle extension and tachometer (see figure C-13). The spreader was loaded manually, using simulant left over from other operations.

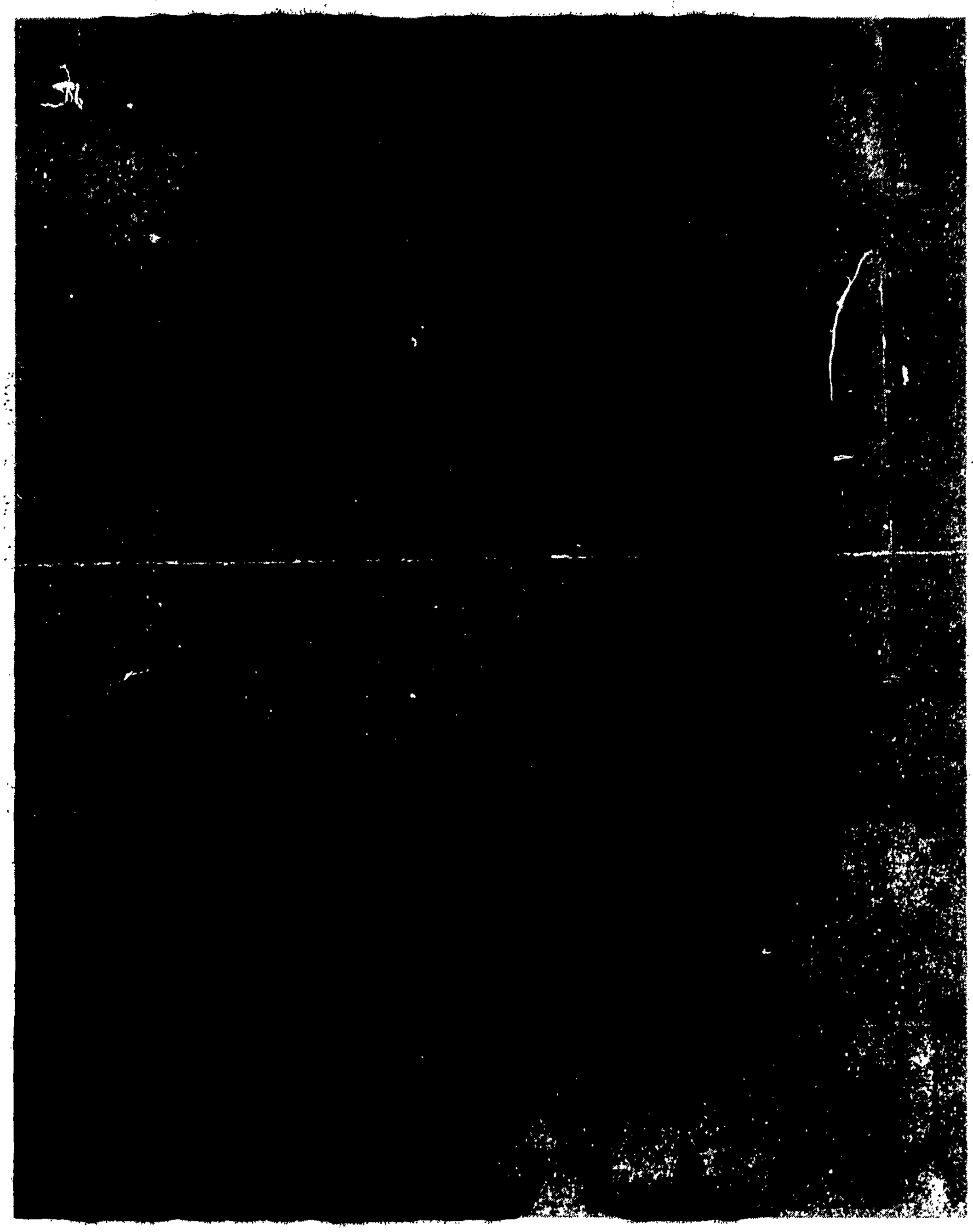


FIGURE C-12

TRANSFERRING SAND FROM HOPPER TO SPREADER

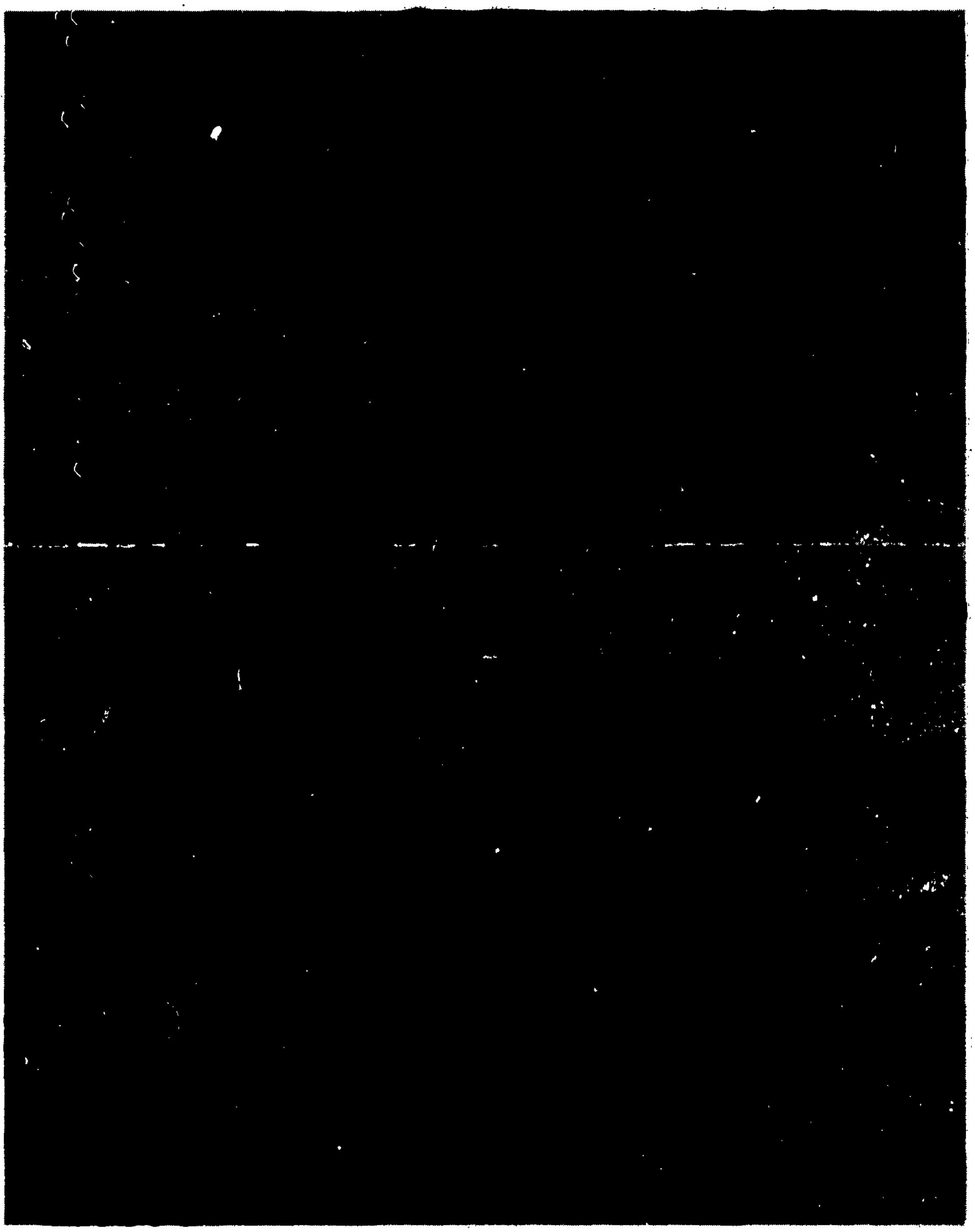


FIGURE C-13

SPREADING FALLOUT SIMULANT ON ROOF

APPENDIX D

EXPERIMENTAL DATA

I. DESCRIPTION OF DATA.

The data collected from the field tests consist of the (1) radiation measurements in milliroentgens per hour at the various positions over the test areas before and after decontamination, (2) mass level and the specific activity of the fallout simulant collected in the sample pans, (3) decontamination time, (4) maximum decontamination equipment operator dose rate, and (5) air temperature.

II. DATA CORRECTIONS.

The radiation measurements taken under field conditions with radiac meters were corrected for instrument calibration, relative position of the meter over the test area, and the decay of the radioisotope on the simulant. Theoretical considerations for neglecting other errors and the method of correction of radiation measurements for meter position were presented in a previous report. *

Correction factors for each of the measurements points, as derived in the above referenced report for a 100 by 20 ft test area, are as follows:

Distance from end of area ft	Distance from side of area At 3.33 ft	At 10 ft	At 16.67 ft
20	1.21	1.04	1.21
40	1.16	1.00	1.16
60	1.16	1.00	1.16
80	1.21	1.04	1.21

All radiation measurements are corrected for decay to the time of decontamination, using the formula

$$I_o = I_R e^{0.017t}$$

* Meredith, John L. Method of Evaluation of Experimental Radiation Measurements Over a Rectangular Source. USA CmlC NDL-TR-11. UNCLASSIFIED Report.

where

I_o = intensity at time of decontamination
I_R = intensity at time of measurement
t = time in hours between decontamination and measurement
e = base of natural logarithm

III. TABULATION OF DATA.

A. Test Data Tables.

The data collected from the field tests are presented in tabular form for each test. The tests are identified by number, type of test surface, and method of decontamination. Included in the test-data tables are the following:

1. Air temperature at the time of decontamination.

2. Dimensions of the test area.

3. Specific mass level (grams per square foot) of simulant collected in sample pans, the pan's position on the test area, and the mean and standard deviations of the mass level.

4. The specific activity (microcuries per gram) of the simulant collected in the sample pans, corrected to the time of decontamination.

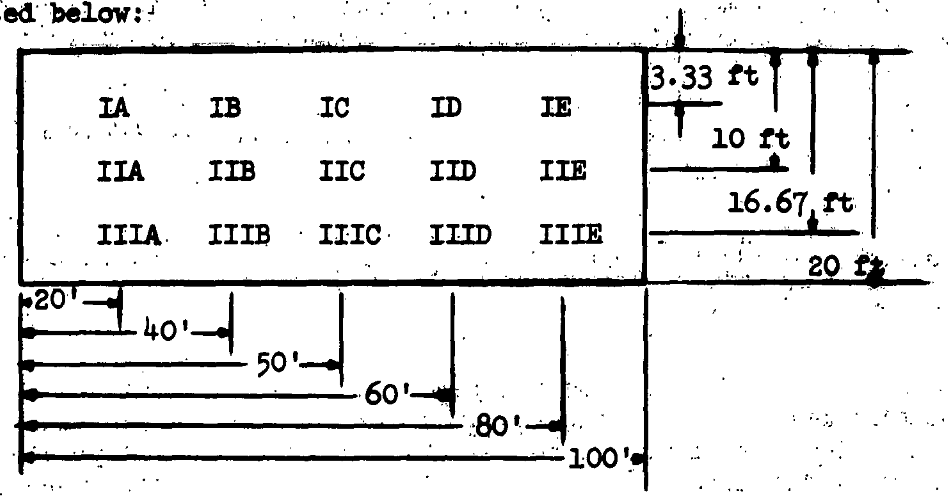
5. Decontamination time required for the test area, which includes maneuvering time.

6. The maximum dose rate received during decontamination by the equipment operator.

7. Observations of factors affecting test measurements, results, or conclusions.

8. Radiation-level measurements taken over the test area corrected for instrument calibration, and the position of each measurement over the test area. The position coding system, applicable for

the radiation measurement and simulant-collection positions, is illustrated below:



B. <u>Analysis of Data</u>.

In addition to the field data, the tables also include radiation measurements corrected for position and decay and calculated percentage of decontamination. Each radiation measurement was corrected by multiplication of the field measurement by applicable position and decay correction factors. The resulting values were analyzed for percentage of decontamination by the following methods:

1. A total-area decontamination percentage was derived for comparison of the various tests in this series. The mean, $\bar{X}$, and the standard deviation, s, of each set of corrected measurements were calculated by the equations

$$\bar{X} = \frac{\Sigma x}{N} \qquad (1)$$

$$s = \sqrt{\frac{\Sigma x^2 - N(\Sigma x)^2}{N - 1}} \qquad (2)$$

where

Σx = sum of measurements
Σx^2 = sums of squares of measurements
N = number of measurements

The percentage of decontamination and 80% confidence range was then calculated from these values as follows (subscript 1 denotes before decontamination and subscript 2, after decontamination):

$$\text{Per cent decontamination} = \frac{\bar{X}_1 - \bar{X}_2}{\bar{X}_1}(100) \tag{3}$$

$$\text{Range} = \frac{100}{\bar{X}_1}\left\{\bar{X}_1 - \bar{X}_2 \pm 0.370\sqrt{s_1{}^2 + s_2{}^2}\left[1 + 0.060\left(\frac{s_1{}^4 + s_2{}^4}{(s_1{}^2 + s_2{}^2)^2}\right)\right]\right\} \tag{4}$$

2. Decontamination percentages were calculated for each measurement point and subsequently analyzed for an over-all mean and range for that test. These results would be used for projection to large or infinite areas. Each point's decontamination percentage was calculated by the equation

$$\text{Per cent decontamination} = 100\,\frac{(x_1 - x_2)}{x_1} \tag{5}$$

The mean ($\bar{X}$) and standard deviation, s, of the decontamination percentages were calculated using equations (1) through (5). The range about the mean percentage was then determined by the equation

$$\text{Range} = \pm 1.282\ s \tag{6}$$

TEST NUMBER I: Bare Frozen Ground Decontaminated by Vacuum Sweeper

1. Air temperature: 31°F
2. Area dimension: 100 x 20 ft
3. Simulant mass level:

Pan position	Mass level gm/sq ft
IE	23.3
IIC	50.6
IIIA	53.3
Mean	42.4
SD	16.6

4. Simulant specific activity: 4.0 μC/gm
5. Decontamination time: 3 min
6. Maximum operator dose rate: 30 mr/hr
7. Observations: The vacuum sweeper did not have room at one end to leave the test area to turn around. It was noted that the contaminant was not picked up under these turns.
8. Radiation measurements:

Position	Contaminated area		Decontaminated area (One pass)		Percentage of decontamination
	Field measurement	Corrected value	Field measurement	Corrected value	
	mr/hr		mr/hr		%
IA	19	23	1.0	1.2	94.8
IB	21	24	1.4	1.7	92.9
ID	20	23	1.4	1.7	92.6
IE	17	21	1.9	2.3	89.0
IIA	25	26	1.4	1.5	94.2
IIB	25	25	1.9	1.9	92.4
IID	22	22	2.0	2.0	90.9
IIE	21	22	2.7	2.9	86.8
IIIA	19	23	1.0	1.2	94.8
IIIB	19	22	1.8	2.1	90.5
IIID	23	27	1.9	2.2	91.9
IIIE	21	25	1.6	2.0	92.0
Mean		23.6		1.9	91.9
SD		1.8		0.5	
Range					86.9 - 94.9

NOTE: Total area decontamination percentage: 91.9
Total area decontamination range percentage: 89.0 - 94.9

TEST NUMBER II: Bare Frozen Ground Decontaminated by Mechanized Sweeper

1. Air temperature: 31°F
2. Area dimension: 100 x 20 ft
3. Simulant mass level:

Pan position	Mass level gm/sq ft
IE	55.3
IIC	42.4
IIIA	34.3
Mean	44.0
SD	10.6

4. Simulant specific activity: 3.8 μC/gm
5. Decontamination time: One pass, 6 min; two passes, 15 min
6. Maximum operator dose rate: 50 mr/hr
7. Observations: All sweeper passes were made in the direction from A to E. The contaminant tended to accumulate ahead of the sweeper.
8. Radiation measurements:

Position	Contaminated area: Field measurement (mr/hr)	Contaminated area: Corrected value (mr/hr)	Decontaminated area, One pass: Field measurement (mr/hr)	Decontaminated area, One pass: Corrected value (mr/hr)	Decontaminated area, Two passes: Field measurement (mr/hr)	Decontaminated area, Two passes: Corrected value (mr/hr)	Percentage of decontamination: One pass (%)	Percentage of decontamination: Two passes (%)
IA	18	22	5	6	1.6	2.0	72.7	90.9
IB	19	22	5	6	2.0	2.4	72.7	89.1
ID	22	26	6	7	2.0	2.4	73.1	90.8
IE	21	25	6	7	4.2	5.2	72.0	79.2
IIA	19	20	5	5	1.4	1.5	75.0	92.5
IIB	21	21	5	5	2.0	2.1	76.2	90.0
IID	20	20	6	6	2.0	2.1	70.0	89.5
IIE	20	21	8	8	3.1	3.3	61.9	84.3
IIIA	17	21	4	5	1.6	2.5	76.2	88.1
IIIB	17	20	4	5	1.6	2.4	75.0	88.0
IIID	20	23	6	7	2.1	2.5	69.6	89.1
IIIE	20	24	10	12	4.2	5.2	50.0	78.3
Mean		22.1		6.6		2.8	70.3	87.5
SD		2.2		2.0		1.2		
Range							67.3-73.3	81.7-93.3

NOTE:

	One pass	Two passes
Total area decontamination percentage:	70.1	87.3
Total area decontamination range percentage:	65.1-75.1	83.3-91.4

TEST NUMBER III: Bare Frozen Ground Decontaminated by Fire Hosing

1. Air temperature: 8°F
2. Area dimension: 100 x 20 ft
3. Simulant mass level:

Pan position	Mass level gm/sq ft
IE	21.5
IIC	47.3
IIIA	28.0
Mean	32.3
SD	13.4

4. Simulant specific activity: 9.0 μC/gm
5. Decontamination time: 10 min
6. Maximum operator dose rate: 10 mr/hr
7. Observations: Fire hosing of frozen ground resulted in an almost immediate glazing of the surface with majority of the contaminant under this thin layer of ice. Continued hosing would not affect this glaze.
8. Radiation measurements:

Position	Contaminated area		Decontaminated area, One pass		Percentage of decontamination
	Field measurement	Corrected value	Field measurement	Corrected value	
	mr/hr		mr/hr		%
IA	21	25	19	25	0.0
IB	22	26	19	24	7.7
ID	20	23	18	23	0.0
IE	22	27	19	25	7.4
IIA	27	28	21	24	14.3
IIB	29	29	25	27	6.9
IID	30	30	25	27	10.0
IIE	29	30	23	26	13.3
IIIA	25	30	22	29	3.3
IIIB	26	30	22	28	6.7
IIID	27	31	22	28	9.7
IIIE	25	30	22	29	3.3
Mean		28.3		26.3	6.9
SD		2.5		2.1	
Range					1.0 - 12.8

NOTE: Total area decontamination percentage: 7.1
Total area decontamination range percentage: 0.4 - 13.8

TEST NUMBER IV: Packed Snow Decontaminated by Fire Hosing

1. Air temperature: 13°F
2. Area dimension: 100 x 20 ft
3. Simulant mass level:

Pan position	Mass level gm/sq ft
IE	47.2
IIC	62.8
IIIA	31.0
Mean	47.0
SD	15.9

4. Simulant specific activity: 8.7 μC/gm
5. Decontamination time: 20 min
6. Maximum operator dose rate: 10 mr/hr
7. Observations: Fire hosing of packed snow resulted in no runoff of water, all of it being immediately absorbed by the snow. The test area was two 50 by 20 ft plots, instead of the reported 100 by 20 ft; however, because of the extremely poor results, no effort was made to correct data for position, except only for decay.
8. Radiation measurements:

Position	Contaminated area	Decontaminated area		Percentage of decontamination
		One pass		
	Field measurement	Field measurement	Corrected value	
	mr/hr	mr/hr		%
IA	29	22	24	17.2
IB	27	27	29	- 7.4
ID	29	22	24	17.2
IE	30	25	27	10.0
IIA	37	31	34	8.1
IIB	33	30	33	0.0
IID	34	25	27	20.6
IIE	31	26	28	9.7
IIIA	36	29	32	11.1
IIIB	26	27	29	- 11.5
IIID	26	22	24	7.7
IIIE	23	17	19	17.4
Mean	30.1		27.5	8.3
SD	4.3		4.3	
Range				0 - 21.9

NOTE: Total area decontamination percentage: 8.6
Total area decontamination range percentage: 1.0 - 16.3

TEST NUMBER V: Bare Roof Decontaminated by Fire Hosing

1. Air temperature: 21°F
2. Area dimension: 60 x 20 ft
3. Simulant mass level: No data
4. Simulant specific activity: 8.8 μC/gm
5. Decontamination time: 15 min
6. Maximum operator dose rate: 5 mr/hr
7. Observations: The position correction factors used for the evaluation of the roof area are different because of the smaller size of the test area, and the equations of statistical analyses are different because of smaller number of measurement points; however, the same methods were employed.
8. Radiation measurements:

Position	Contaminated area		Decontaminated area one pass		Percentage of decontamination
	Field measurement	Corrected value	Field measurement	Corrected value	
	mr/hr		mr/hr		%
IA	17	20	2.8	3.6	82.0
IB	17	20	2.2	2.8	86.0
ID					
IE					
IIA	17	17	3.3	3.6	78.8
IIB	19	19	2.2	2.4	87.4
IID					
IIE					
IIIA	13	15	2.9	3.7	75.3
IIIB	17	20	2.0	2.6	87.0
IIID					
IIIE					
Mean		18.5		3.1	82.8
SD		6.6		0.6	
Range					76.5-89.1

NOTE: Total area decontamination percentage: 83.2
Total area decontamination range percentage: 64.9 - 100.0

TEST NUMBER VI: Packed Snow Decontaminated by Motor Grader

1. Air temperature: 24°F
2. Area dimension: 100 x 20 ft
3. Simulant mass level:

Pan position	Mass level gm/sq ft
IE	45.0
IIC	59.9
IIIA	38.5
Mean	47.8
SD	11.0

4. Simulant specific activity: 9.3 μC/gm
5. Decontamination time: 15 min Windrow removal: 60 min
6. Maximum operator dose rate: 10 mr/hr
7. Observations: A noticeable amount of contaminant worked its way under the blade, requiring the area to be scraped twice. The blade angle was set to allow no snow to fall over the blade. Results listed under "One pass" are measurements taken after two scrapes with the windrow 10 ft from the III side of the area. Data under "Two passes" were collected after the windrow had been removed.
8. Radiation measurements:

Position	Contaminated area		Decontaminated area				Percentage of decontamination	
			One pass		Two passes			
	Field measurement	Corrected value	Field measurement	Corrected value	Field measurement	Corrected value	One pass	Two passes
	mr/hr		mr/hr		mr/hr		%	
IA	19	23	6	8	4	5	65.2	78.3
IB	22	26	5	6	5	6	76.9	76.9
ID	25	29	7	9	4	5	69.0	82.8
IE	23	28	5	7	4	5	75.0	82.1
IIA	26	27	7	8	5	6	70.4	77.8
IIB	26	26	8	9	6	7	65.4	73.1
IID	30	30	10	11	9	10	63.3	66.7
IIE	25	26	8	9	4	5	65.4	80.8
IIIA	19	30	9	12	6	8	47.8	65.2
IIIB	22	26	9	12	7	9	53.8	65.4
IIID	22	26	11	14	9	12	46.2	53.8
IIIE	19	23	8	11	5	7	52.2	69.6
Mean		26.1		9.7		7.1	62.6	72.7
SD		2.3		2.3		2.3		
Range							49.5-75.7	61.5-83.9

NOTE:	With windrow	Without windrow
Total area decontamination percentage:	62.8	72.8
Total area decontamination range percentage:	58.2 - 67.4	65.5 - 80.1

TEST NUMBER VII: Packed Snow Decontaminated by Vacuum Sweeper

1. Air temperature: 25°F
2. Area dimension: 100 x 20 ft
3. Simulated mass level:

Pan position	Mass level gm/sq ft
IE	47.7
IIC	32.5
IIIA	0.0
Mean	26.7
SD	24.4

4. Simulant specific activity: 8.5 μC/gm
5. Decontamination time: 20 min
6. Observations: The sweeper repeatedly became stuck on the relatively smooth packed snow, requiring it to be towed by another vehicle to get started.
7. Radiation measurements:

Position	Contaminated area		Decontaminated area, Two passes		Percentage of decontamination
	Field measurement	Corrected value	Field measurement	Corrected value	Two passes
	mr/hr		mr/hr		%
IA	29	35	7	9	74.3
IB	26	30	7	9	70.0
ID	23	27	7	9	66.7
IE	22	27	7	9	66.7
IIA	27	28	7	8	71.4
IIB	26	26	8	9	65.4
IID	25	25	8	9	64.0
IIE	22	23	7	8	65.2
IIIA	17	21	6	8	61.9
IIIB	17	20	5	6	70.0
IIID	17	20	6	7	65.0
IIIE	17	21	6	8	61.9
Mean		25.3		8.3	66.9
SD		4.6		1.0	
Range					62.0 - 71.8

NOTE: Total area decontamination percentage: 67.2
Total area decontamination range percentage: 55.7 - 78.7

TEST NUMBER VIII: <u>Packed Snow Decontaminated by Mechanized Sweeper</u>

1. Air temperature: 26°F
2. Area dimension: 100 x 20 ft
3. Simulant mass level:

Pan position	Mass level gm/sq ft
IE	29.2
IIC	46.2
IIIA	25.8
Mean	33.7
SD	10.9

4. Simulant specific activity: 8.9 μC/gm
5. Decontamination time: 20 min
6. Observations: Reported data are for two passes. After one pass, it was visually determined that a second pass would be required.
7. Radiation measurements:

Position	Contaminated area: Field measurement	Contaminated area: Corrected value	Decontaminated area, One pass: Field measurement	Decontaminated area, One pass: Corrected value	Percentage of decontamination: One pass
	mr/hr		mr/hr		%
IA	26	31	7	9	71.0
IB	30	35	7	9	74.3
ID	33	38	8	10	73.7
IE	30	36	9	12	66.7
IIA	29	30	8	9	70.0
IIB	30	30	7	8	73.3
IID	31	31	7	8	74.2
IIE	26	27	7	8	70.4
IIIA	22	27	5	6	77.8
IIIB	26	30	6	7	76.7
IIID	25	29	4	5	82.8
IIIE	23	28	4	5	82.1
Mean		31.0		8.0	74.4
SD		3.5		2.0	
Range					68.2 - 80.6

NOTE: Total area decontamination percentage: 74.2
Total area decontamination range percentage: 66.1-82.3

TEST NUMBER IX: Loose Snow on Packed Snow Decontaminated by Motor Grader

1. Air temperature: 24°F
2. Area dimension: 100 x 20 ft
3. Simulant mass level:

Pan position	Mass level gm/sq ft
IE	43.0
IID	46.4
IIIA	6.2
Mean	31.9
SD	22.2

4. Simulant specific activity: 5.4 μC/gm
5. Decontamination time: 10 min
6. Observations: This test was a little different than test VI because the loose snow was about a week old. The windrow was pushed into a ditch beside the test area. Two scrapes were made.
7. Radiation measurements:

Position	Contaminated area		Decontaminated area One pass		Percentage of decontamination
	Field measurement	Corrected value	Field measurement	Corrected value	One pass
	mr/hr		mr/hr		%
IA	21	25	6	7	72.0
IB	21	24	7	8	66.7
ID	21	24	7	8	66.7
IE	21	25	7	9	64.0
IIA	21	22	7	7	68.2
IIB	21	21	9	9	57.1
IID	21	21	7	7	66.7
IIE	21	22	7	7	68.2
IIIA	13	16	7	9	43.8
IIIB	15	17	8	9	47.1
IIID	17	20	8	9	55.0
IIIE	17	21	6	7	66.7
Mean		21.5		8.0	61.9
SD		2.9		1.0	
Range					51.6-72.2

NOTE: Total area decontamination percentage: 62.8
Total area decontamination range percentage: 54.0-71.6

APPENDIX E

HEALTH-PHYSICS DATA

I. GENERAL.

The exhaustive dry runs and rehearsals, in addition to a liberal application of applied shielding everywhere it would fit, resulted in no significant radiation doses to personnel. The highest total dose absorbed was 0.3 r for any one person. There were no above-tolerance aerosols detected, and no change in the radiation background environment of the camp that could be attributed to this project. One month after operations ceased, radiation surveys made by the Cook Research Laboratories, Morton Grove, Illinois, and the Health Physics Office of this Laboratory were negative.

II. IMPURITIES IN IRRADIATED MATERIALS.

Two capsules of La_2O_3, irradiated at Argonne National Laboratories (ANL), were allowed to decay for 5 mo so that the La^{140} should be completely undetectable. Any residual activity would be due to impurities in the material irradiated. Experimentation at this Laboratory has revealed that the minute residual activity in the capsules is approximately 20% cesium-134 (Cs^{134}) and the remainder a mixture of the three isotopes of europium (Eu). The total activity released at Camp McCoy, Wisconsin, decayed to $< 50\ \mu C$ after 30 days. Practically all waste was carefully buried in accordance with Atomic Energy Commission (AEC) regulations, in the restricted buffer-zone area next to the North Impact Area of the camp. The quantity of Cs^{134} and rare earth isotopes buried is about half that allowed by the AEC in one disposal pit for an unknown mixture of isotopes.

III. PRODUCTION-AREA DOSE LEVELS.

Presented below is a summary of dose levels in the simulant-production area for all operations there, in addition to a schedule for the most active production run (see tables E-1 and E-2).

TABLE E-1

SUMMARY OF DOSE LEVELS IN THE SIMULANT-PRODUCTION AREA a/

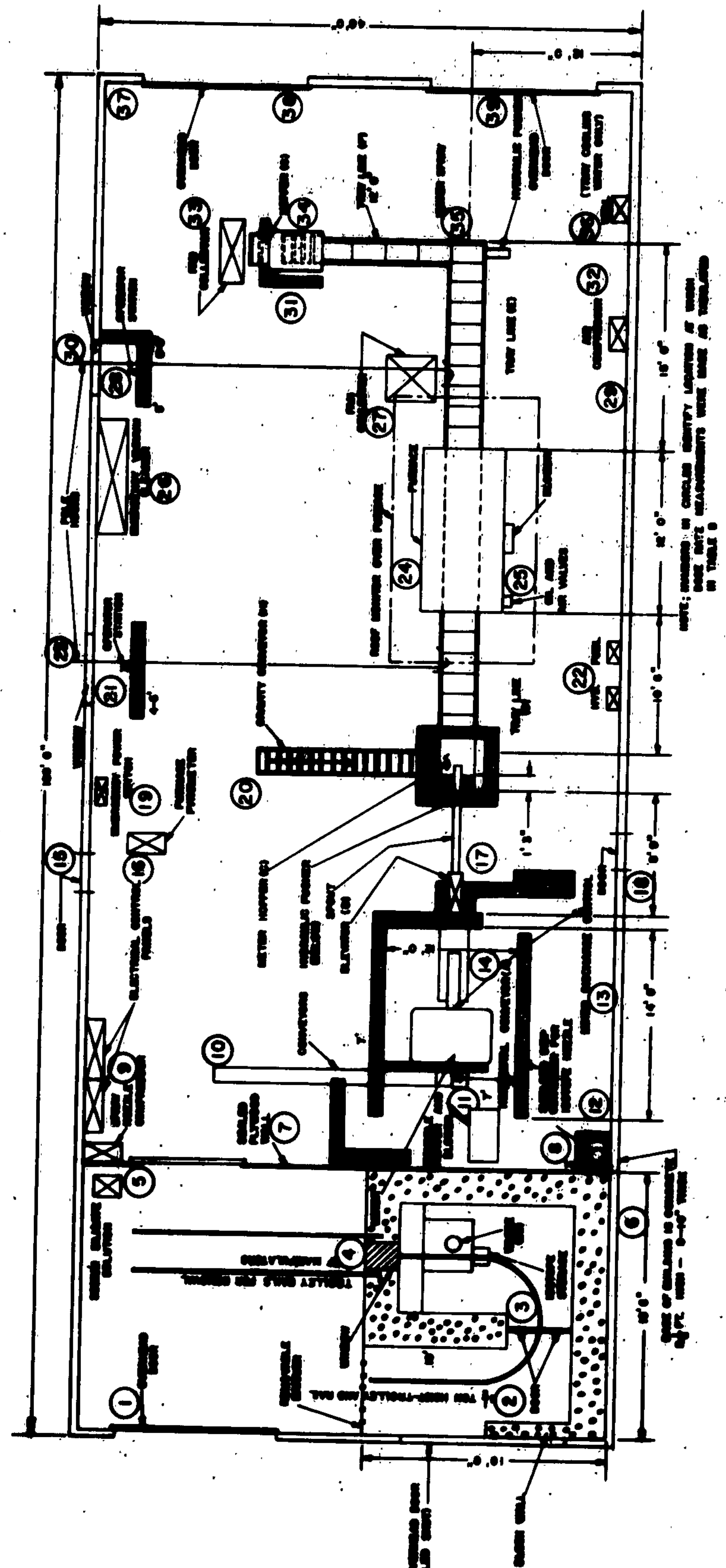
Location	Date and time of day dose levels were taken in 1961										
	Mar 7 1340	Mar 8 1215	Mar 9 1105	Mar 9 2050	Mar 10 1000	Mar 14 1030	Mar 15 0837	Mar 16 1445	Mar 17 0910	Mar 20 1315	Mar 21 1120
						mr/hr					
1	0.01	0.01	0.01	0.6	3.2	0.2	2	0	0.15	0.05	0.03
2	0.01	0.5	b/	b/	b/	0.3	b/	0	10	5	5
3	0.01	0.5	b/	b/	b/	b/	b/	40	55	b/	b/
4	0.01	0.05	0.01	0.8	3.0	0.2	10	0	0.2	0.05	0.05
5	0.01	0.01	0.01	1.0	1.0	0.1	1.8	0	0.35	0.15	0.1
6	b/	0.01	0.01	b/	0.5	0.1	2.8	1	0.3	0.1	0.05
7	0.01	0.05	0.01	1.0	0.1	1	2.6	1	2	0.05	0.05
8	0.01	0.05	0.01	60	b/	6	20	1	5	1	1.5
9	0.01	0.01	0.01	1.5	1.6	1	0.8	1	0.2	0.05	0.05
10	0.01	0.01	0.01	3.2	1.8	0	1.6	1	0.4	0.15	0.1
11	0.01	0.05	0.01	375	b/	0	100	50 c/	10	40	4
12	0.01	0.01	0.01	120	b/	10	5	6	2	0.3	0.5
13	0.01	0.01	0.01	60	b/	0.4	10	4	0.3	0.1	0.15
14	0.01	0.01	0.01	b/	b/	35	300	40	25	3	35
15	0.01	0.01	0.01	b/	1.6	0	3	3	1	0.1	0.05
16	0.01	0.01	0.01	1.3	5.0	0	6	2	1	0.2	0.1
17	0.01	0.01	0.01	6.0	b/	18	46	20	25	10	2
18	0.01	0.01	0.01	2.0	8.0	0.1	4	21	2.5	0.3	0.15
19	0.01	0.01	0.01	b/	1.0	0	4.6	2	2	b/	0.2
20	0.01	0.01	0.01	2.2	8.0	1.4	8	8	1	2	1
21	0.01	0.01	0.01	1.0	0.8	0	6	1	0.5	0.05	0.05
22	0.01	0.01	0.01	1.0	b/	1	6	55	3	1	0.3
23	0.01	0.01	0.01	b/	b/	0	5	1	0	0.02	0.03
24	0.01	0.01	0.01	1.2	b/	0	22	2	12	10	1.25
25	0.01	0.01	0.01	1.2	b/	0	2.8	7	15	2.5	0.35
26	0.01	0.01	0.01	1.0	b/	10	10	2	1	0.2	0.08
27	0.01	0.01	0.01	0.4	b/	0.1	100	1	1.5	0.2	0.2
28	b/	0.01	0.01	0.5	b/	0	4	1	0.2	0.05	0.05
29	0.01	0.01	0.01	b/	b/	0	6	0	1	0.2	0.03
30	b/	0.01	0.01	b/	1.2	0	3	0	0	0.1	0.03
31	0.01	0.01	0.01	0.8	b/	5	20	0	2	0.2	0.1
32	0.01	0.01	0.01	0.5	b/	0	12	0	1.5	0.1	0.05
33	0.01	0.01	0.01	0.2	b/	0.8	4	1	1.5	0.2	0.05
34	0.01	0.01	0.01	0.2	b/	100	120	4	6	1	0.1
35	0.01	0.01	0.01	0.3	b/	0.6	100	0	1	0.05	0.1
36	0.01	0.01	0.01	0.4	b/	0	30	0	0.6	0.1	0.05
37	0.01	0.01	0.01	0.3	5.0 d/	1	14	1	2	0.15	0.1
38	0.01	0.01	0.01	b/	7.0 d/	5	14	3	2	0.2	0.05
39	0.01	0.01	0.01	b/	4.0 d/	0	12	1	1	0.1	0.05

a/ See figure
b/ No data
c/ 2.5 r/hr (Lance, hand dose, maximum) March 16 at 0200 hr
d/ Outside building along wall at these points

TABLE E-2

OPERATING SCHEDULE, 15 AND 16 MARCH 1961 FOR 1,500 POUNDS OF SAND

Procedure	First 500 lb hr	Second 500 lb hr	Third 500 lb hr
Start furnace	0715		
Load sand in mixer	0715	1145	1640
Isotope injection	0830	1310	1805
Silicate injection	0837	1315	1810
Start drying	0917	1346	1939
Dump mixer	1117	1615	2200
1st half to furnace	1140	1630	2225
1st half out of furnace and 2nd half to furnace	1240	1730	2325
1st half to final hopper	1800	2100	0200
2nd half to final hopper	1900	2200	0300
All sand in loading hopper	----	----	0400
Clean up and secure building	----	----	0430



FIGURE

FALLOUT SIMULANT PRODUCTION FACILITY

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The objective of this work was to obtain data on the efficiency of decontamination techniques under below-freezing conditions when applied to outdoor surfaces. Fallout simulant was prepared by tagging 150μ to 300μ sand with lanthanum-140. The simulant was then dispersed onto snow, frozen soil, and roof surfaces. The techniques of fire hosing, snow plowing, and power sweeping were tested. The experimental effort was limited by improper weather conditions.

1. Decontamination
2. Radioactive Fallout
3. Climate, Cold
4. Engineer Equipment

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